Flathead Basin Commission

BIENNIAL REPORT

1997-1998

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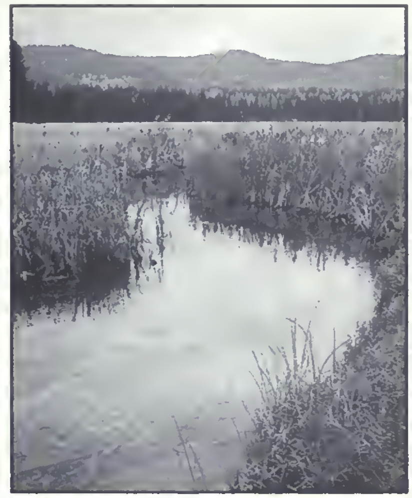


Letter from the Chair

Dear Members of the Legislature and Governor Racicot:

To those of you who were present for the 1997 legislative session, much of what you'll read in the Flathead Basin Commission's Biennial Report will have a ring of familiarity. New legislators will find the report an expedient way of briefing themselves on the unique partnership of the Commission and the state in working to solve water quality problems in one of Montana's most important watersheds.

It was the 1997 session which recognized the importance of finding new ways to address the state's pressing water quality issues. The session wrote Total Maximum Daily Load (TMDL) legislation which will guide agencies and citizens throughout the state in devising ways of cleaning up Montana's impaired water bodies. In doing so, the legislature insured that the important economic, cultural and aesthetic value of the state's water will be maintained and enhanced for future generations.

The Flathead Basin Commission has the unique responsibility of being the state's representative in carrying out the TMDL process in the Flathead watershed. Our goal is to reduce nonpoint source pollution to Flathead Lake to a level where the lake can be removed from the U.S. EPA's list of impaired water bodies. The process begins in earnest this year, with an all out effort to involve citizens throughout the basin in a partnership with a wide variety of agencies to reduce pollution sources. The effort will emphasize voluntary and non-regulatory solutions, and will result not only in improved water quality for Flathead Lake, but cleaner water in lakes and streams throughout the basin.

A great deal is at stake. Maintaining and improving water quality is directly linked to sustaining the area's economic growth. Property values, the local tax base, and jobs are all on the line when water quality levels drop. Working to meet TMDL goals will insure that this vital economic asset will be protected and enhanced.

The legislature's vision in creating the Flathead Basin Commission is verified by today's realities. Protecting water quality is more essential now than ever before. In 1999, and in years to come, we look forward to working closely with the legislature and Montana citizens to protect and preserve this most precious natural resource.

The TMDL process give us an opportunity to do that in a dynamic way that will involve the basin's residents as key partners in achieving mutual goals. The continued understanding and support of the legislature is essential. We look forward to the continuation of this cooperative relationship, which benefits the citizens of the Flathead Basin and all Montanans.

Sincerely,

Dave Mihalic

David Mihalic, Chair

Conclusions & Recommendations of the Flathead Basin Commission

Unusually high precipitation and subsequent flooding during the 1997 water year produced elevated levels of pollutants at river monitoring sites in the upper Flathead Valley and in Flathead Lake. While reflective of land management practices in the semi-urban valley floor, monitoring results during that period do not suggest a trend that would continue under more normal water conditions.

The Commission recognizes that water quality in the basin remains impaired, but acknowledges progress as reflected by results of the most recent Forestry Best Management Practices audit and an improvement in bull trout redd counts in several drainages. Please refer to page 46 for the complete Summary of Monitoring Findings.

The Commission recommends the following priorities during the 1999 — 2000 biennium:

1) Watershed Coordination

- Maintain a dialog with British Columbia on cross border watershed issues; encourage the B.C. government to maintain its liaison position with the FBC; and continue biannual North Fork information exchange meetings.
- Reestablish positive relationships with local and tribal governments.

2) Monitoring

- Maintenance of the historical monitoring plan for Flathead Lake is critical; monitoring of semi-urban valley areas upstream from Flathead Lake is of equal importance.
- Monitor nonpoint "hot spots," in light of future growth, recognizing the likelihood of successful pollution reduction diminishes without such monitoring information.

3) Funding

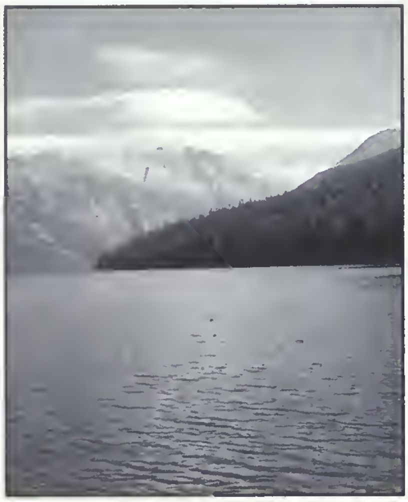
- Seek legislative approval of an $80,000 annual appropriation for Flathead Lake monitoring.
- Pursue long-term funding from private, local government, tribal and other sources, including in-kind contributions, for annual $55,000 monitoring budget for semi-urban valley areas upstream from Flathead Lake.

4) Total Maximum Daily Load (TMDL)

- Implement a non-regulatory, voluntary effort to reduce nonpoint sources of pollution through an incentive-based program, utilize existing groups and organizations, and encourage the active involvement of local citizens.

5) Public Education

- Increase local understanding and use of Best Management Practices (BMPs) through workshops for small acreage landowners.
- Use newsletters, media outreach, programs for schools and community groups and other means to inform the public of the Commission's activities and water quality issues.
- Develop Commission website as an information resource.
- Recognize commendable practices or contributions of local citizens and/or organizations.



The Commission

Who We Are, What We Do

Created by the Montana Legislature to monitor and protect water quality in the state's most important watershed, the Flathead Basin Commission is a uniquely structured non-regulatory organization that works to accomplish its important mandate in a consensus-building manner, stressing education, cooperation, broadly-based community involvement and voluntary participation.

The 21 members of the Commission represent a wide cross-section of citizens and local, state, tribal, federal and provincial agency representatives who strive to identify the basin's water quality problems and work collectively to implement the most effective solutions.

The Commission's six citizen members are appointed by the governor, and serve without any form of compensation. Coming from communities throughout the Flathead watershed and a representing a wide variety of viewpoints, the citizen members insure the public's interests are considered and respected in every aspect of the Commission's activities.

The Flathead Basin Commission has become a model of successful citizen, inter-agency cooperation in a geographically vast and ecologically diverse watershed characterized by its overall pristine character, international dimensions, and multi-jurisdictional nature.

Among the duties of the Flathead Basin Commission as defined by law are:

- to encourage economic development and use of the basin's resources to their fullest extent without compromising the present high quality of the basin's waters,
- to monitor the existing conditions of the natural resources in the basin and coordinate development of an annual monitoring plan,
- to encourage close cooperation and coordination between federal, state, tribal and local resource managers, and
- to encourage and work for international cooperation and coordination between the State of Montana and the Province of British Columbia concerning resource development activities in the North Fork of the Flathead River.

The full text of the Commission's amended establishing legislation may be found on page 49.

This report summarizes the Commission's activities, initiatives and water quality monitoring data collected and analyzed during 1997-1998. Those wishing more detailed information regarding any aspect of the Commission and its activities are encouraged to us.

Flathead Basin Commission
33 2nd Street East
Kalispell, Montana 59901

The Flathead Basin

A World Class International Watershed

The Flathead River basin is truly unique among watersheds in the world's temperate zone.

The creation of what today is known as the Flathead Basin can be traced to momentous geological activity that led to the formation of the Rocky Mountains 150 million years ago. About three million years ago, glacial activity began with a series of "ice ages" in the Northern Rockies, gradually shaping the physical character of the land and sculpting the river valleys and mountain ranges into what we today know as the Flathead Basin. Such significant geological attributes as Flathead Lake and the glaciers in Glacier National Park are living reminders of the end of the last ice age, a mere 10,000 years ago.

Located in northwestern Montana and southeastern British Columbia, the watershed encompasses 8,587 square miles (approximately six million acres). The basin is larger than the combined territory of Puerto Rico and the states of Delaware and Rhode Island. The long, north-south axis stretches 175 miles, while the maximum width is 88 miles.

The Flathead River drainage is the largest tributary to the Clark Fork River, part of the extensive headwaters of the Columbia River. The Flathead's three forks — North, Middle and South — together supply approximately 80 percent of the water carried within the watershed. Other rivers in the basin include the Stillwater, Whitefish and Swan. The lower Flathead River — that portion below the outlet of Flathead Lake at the town of Polson — empties into the Clark Fork River at the town of Paradise at an elevation of 2,500 feet above sea level.

Elevations elsewhere in the watershed range from Mount Stimson in Glacier National Park at 10,142 feet to 2,893 feet at Flathead Lake, the basin's major catchment. The lake is one of the 300 largest lakes in the world and the largest body of fresh water in the U.S. west of the Mississippi River with a full pool surface area of 126,000 acres. The basin's 500 other lakes range in size and character from nearly inaccessible alpine lakes of only several surface acres to such other significant large water bodies as Swan, McDonald, Whitefish, Tally, and Little Bitterroot lakes.

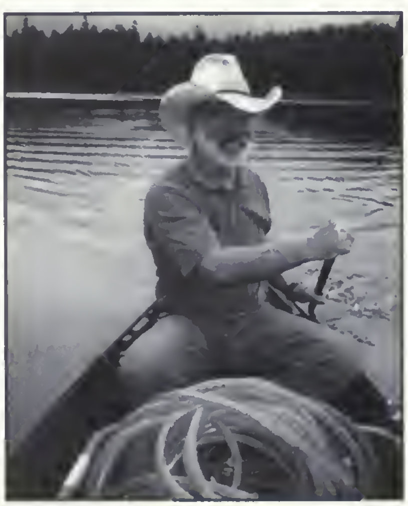
The watershed maintains remarkably diverse communities of plants and animals, including over 300 species of aquatic insects, 22 native and introduced species of fish. The grizzly bear, bald eagle, bull trout and water howellia (aquatic plant present in the Swan Valley) are currently listed under the federal Endangered Species Act as threatened, while the peregrine falcon and grey wolf are listed as endangered.

Included in the watershed are virtually all of Flathead and Lake counties; a segment of Missoula County; the Flathead Indian Reservation; the portion of Glacier National Park west of the continental divide; parts of three wilderness areas; millions of acres of forest land under federal, provincial, state, tribal and corporate management; and thousands of acres of privately owned property.

For a more detailed discussion of the watershed's physical features, refer to *Flathead River Basin Environmental Impact Study Final Report,* available at area libraries or at the Commission office.

Stream bank erosion is a major source of nonpoint pollution in the Flathead watershed. Finding ways to reduce such nonpoint source pollution will be critical to the Commission's Flathead Lake TMDL project.

John O'Cain is a volunteer monitor on Peterson and Abbott lakes, two small bodies of water north of Bigfork. Volunteers provide essential information on water quality trends on three dozen lakes in the Flathead watershed.



Watershed Planning and Nutrient Reduction

Tackling pollution at the source

The ultimate goal of the Commission's watershed planning effort is to improve the water quality of Flathead Lake. In the process, streams and lakes throughout the watershed will benefit from improved public understanding of water quality issues and a variety of efforts to reduce pollution through actions taken at the neighborhood level by those most affected. Successfully carried out, the process will:

- **Insure that the solution to the Flathead's water quality problems is designed and carried out by local organizations with the active involvement of area citizens.**
- **Respect property rights and protect property values through the enhancement of water quality.**
- **Benefit economic growth that depends on the presence of a high level of water quality.**
- **Maximize the effective use of limited governmental and public financial and human resources.**

Working to Protect a Vital Resource

In response to the designation of Flathead Lake as an impaired water body, under Clean Water Act Section 303(d), the Commission, MDNRC, MDHES (now MDEQ), and the Confederated Salish and Kootenai Tribes collaborated in 1994 on a successful Water Development and Renewable Resource Development Grant to address long term watershed planning in the Flathead Basin.

The effort is viewed as the logical follow-up to the 1984 Phosphorus Reduction Strategy for Flathead Lake, a successful nutrient reduction effort initiated by MDHES based on water quality data collected by the Commission.

With funds provided by a U.S. EPA grant, the Commission coordinated an intensive, multi-agency, basin-wide study of nonpoint source pollution upstream from Flathead Lake and on the lake's shoreline. Information from that landmark two year study will be used to create an effective plan to reduce levels of nitrogen and phosphorus entering the lake

through upstream and shoreline sources. When successful, the plan will achieve the U.S. EPA-established Total Maximum Daily Load (TMDL) levels for pollutants and lead to the removal of Flathead Lake from the impaired water bodies list.

Aaron Miller, a volunteer monitor who works on local streams, inspects Ashley Creek west of Kalispell. The stream is among the most polluted water bodies in the Flathead watershed.

Voluntary Reduction of Nutrient Pollution

In 1999, the Commission begins the challenging process of working with citizens throughout the basin and its agency partners to accomplish nutrient reduction goals for Flathead Lake. Throughout the ongoing effort, the Commission will stress voluntary, non-regulatory approaches to local nonpoint pollution problems.

With information developed through the study of pollution sources upstream from Flathead Lake, the Commission will be able to focus its resources on a number of sub-watersheds where nonpoint pollution is most evident and where opportunities for success are greatest. The project is funded by the MDNRC grant referenced under Voluntary Nutrient Reduction Strategy (VNRS) Education Project on page 53. To accomplish this ambitious goal, the Commission will:

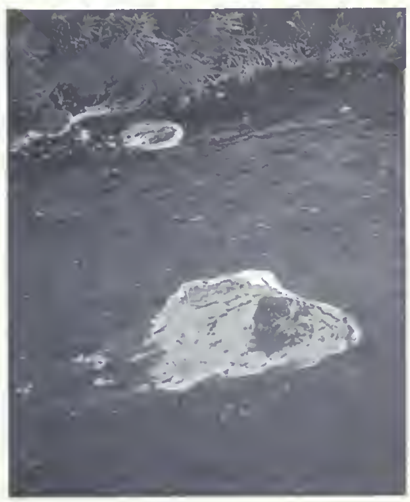
- **Utilize the expertise of KirK Environmental, the firm selected through a competitive process to undertake the Commission's voluntary nonpoint pollution reduction effort. KirK will carry out an education program designed to involve citizens in a number of local watersheds in efforts to reduce nonpoint source pollution.**

- **Work closely with MDEQ's watershed coordinator and monitoring technician to maximize the efficient use of state resources in the Flathead watershed planning and nutrient reduction effort.**

- **Encourage the active involvement of the Commission's agency members and other organizations within the watershed to assist in the coordinated effort to achieve TMDL nutrient reduction targets.**

- **Work with Kirk Environmental and others to seek out and secure alternate sources of funding to enhance nutrient reduction efforts in local watersheds.**

Poor land management practices may result in deteriorated water quality. The Commission will work with local land owners to reduce runoff, erosion and other factors that contribute to nutrient loading.



The TMLD-driven process to reduce nutrient loading to Flathead Lake affords the Commission a timely opportunity to engage Flathead area citizens and organizations in a dynamic, basin-wide effort to protect the region's most important natural resource, its irreplaceable water quality.

For additional information on the Commission's watershed planning initiative, please request a copy of *Water Quality Data and Analyses in the Development of Revised Water Quality Targets for Flathead Lake, Montana,* available at the Commission office, or at our website, **www.montanaweb.com/FBC/**.

Volunteer monitor Stan Shoemaker takes dissolved oxygen readings on Ashley Lake. Evidence of oxygen depletion is one indication of deteriorating water quality.

Monitoring

The Key to Effective Planning and Action

As the Commission intensifies efforts to reduce nonpoint pollution sources throughout the Flathead Basin, maintaining a comprehensive and effective water quality monitoring program becomes all the more important. Efforts to reduce nutrient loading to Flathead Lake will not achieve the maximum potential unless reliable monitoring practices are in place to document the effectiveness of pollution reduction efforts.

Coordination of water quality monitoring in the Flathead watershed is one of the Commission's most important responsibilities. Working closely with agency partners throughout the basin avoids costly duplication of effort and insures the greatest public benefit for dollars spent.

Ascertaining the effectiveness of the Commission's nutrient reduction strategy will become an increasingly important aspect of water quality monitoring in the Basin. As the first step in working to reducing pollution sources upstream from Flathead Lake, the Commission adopted Recommended Water Quality Targets and Load Reduction (February 1998), which will be used to monitor the effectiveness of efforts to reduce nonpoint pollution throughout the basin.

The Commission established an interim target of 80 grams of carbon at the mid lake deep site, and specified that monitoring must provide:

- **Evidence of no measurable blooms of anabaena (or other pollution algae),**
- **no declining trend in oxygen concentrations in the hypolimnion, or**
- **algal biomass measured as Chlorophyll *a* (e.g., near shore rocks on lake bottom) remains stable or exhibits a declining trend.**

The complete text of the TMDL Water Quality Targets and Load Reduction is available from the Commission office.

The Commission uses a Monitoring Master Program to prioritize efforts, assign responsibilities, and insure a coordinated approach that results in the most reliable information possible about the quality of the basin's waters. The program is the result of information provided by researchers and technicians from cooperating agencies and input from Commission members. In general, the program considers the following three general objectives:

- **Monitoring the water quality, quantity and aquatic life of Flathead Lake and its major tributaries.**

Residents of Echo Lake worked with MFWP to monitor boating safety and wake violations. Excessive wave action may lead to shoreline erosion and worsening water quality.

- **Monitoring the water quality, quantity and aquatic life from representative catchments of the upper basin.**

- **Monitoring bull trout populations and habitat in the basin.**

Monitoring includes a wide variety of chemical and limnological parameters, discharge data, water temperature, elevation, fish populations, habitat and other relevant information.

Unfortunately, funding has proven to be inadequate to accomplish the full range of the Commission's monitoring objectives. To focus scarce financial resources on the most critical tasks, the monitoring technical committee proposed a new set of objectives, organized in the following descending order of priority, with projected annual budget:

- **Flathead Lake ($80,000)**

- **Semi-urban, upper Flathead Valley, nonpoint sources ($55,000)**

- **Wilderness, including Glacier National Park and Flathead National Forest sites ($92,000)**

- **Managed forests, including major sub-basins ($35,000) and paired sub-basins ($108,000)**

Monitoring Master Program Funding

The Commission works with a variety of participating agencies and non-profit groups that provide a variety of funding and in-kind support to achieve the program's objectives.

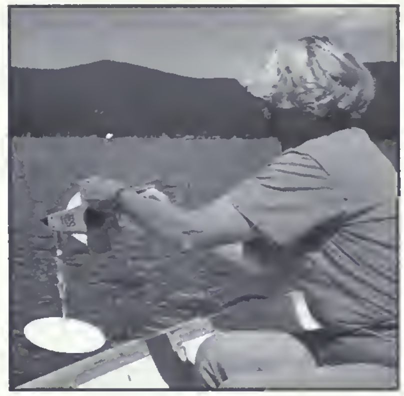
Agencies and organizations contributing funds during the biennium included MDEQ, MDNRC, Flathead National Forest, Glacier National Park, Bureau of Reclamation, Montana Power Company, Flathead Lakers, Trout Unlimited, Polson Community Development Corporation, Lake County Community Development, Friends of the Wild Swan, and Polson Outdoors, Inc.

Contributions of in-kind services, including personnel and equipment, were made by Flathead National Forest, Glacier National Park, MDNRC, MFWP, MDNRC, Flathead Lake Biological Station, Confederated Salish and Kootenai Tribes, and Plum Creek Timber, Inc.

A technical summary of the past two year's water quality monitoring begins on page 20.

Volunteer Monitor Program

The use of citizen volunteers to monitor water quality provides information that complements data gathered by agency scientists. In the case of many small lakes in the Flathead Basin, volunteer-generated data is the only water quality information available. Volunteer water quality data has been used by federal, state and local agencies for a variety of purposes.



Volunteer monitor Virginia Halgren lowers a secchi disk into Lake Mary Ronan to record water clarity. More turbid water indicates the presence of algae, suspended sediments and other pollutants.

Volunteer monitor Susie Bouton records water quality data on Bailey Lake north of Columbia Falls. Volunteers also work to educate their neighbors on the benefit of better land management practices.

Guy Laurendeau and Shirley Harrison prepare for water quality data gathering on Flathead Lake. Bigfork resident Laurendeau monitors two sites, while Lakeside resident Harrison volunteered to work at all of the 14 Flathead Lake sites in 1998.

Training citizens to gather water quality information strengthens the Commission's ties to the community. Program participants have become increasingly active in informing their neighbors of importance of maintaining a high level of water quality. Through their involvement, volunteers have also gained a heightened understanding of the relationship between land management practices and water quality.

Highlights of the program, now in its seventh year, include:

- **The active participation of over 50 volunteers who conduct routine monitoring activities on 50 sites on 29 lakes throughout the Flathead Basin, including Flathead, Lake and Missoula counties.**

- **Since the program's inception in the fall of 1992, volunteers have filed 1,820 monitoring reports, providing invaluable information on lakes throughout the watershed.**

- **The program was the pioneer organized volunteer monitoring effort in the state, and remains one of the largest in the Pacific Northwest region. Volunteers also participate in annual nationwide monitoring exercises coordinated by Kent State University, helping provide an accurate picture of water quality in lakes coast-to-coast.**

The quest for additional water quality information led to the creation of a new program to focus on streams in the watershed. In 1998, the Commission collaborated with the Montana Watercourse, a MDNRC program based at Montana State University in Bozeman, to train and equip volunteers.

- **Twenty seven volunteers were trained and assigned streams for their field work. Volunteers have begun to gather chemical, biological and flow information from streams throughout the Flathead Basin, from the North Fork to the Mission Valley.**

- **Volunteer-gathered data will be maintained at the Commission office and by the Natural Resource Information Center at the State Library in Helena. It will provide useful insights into the quality of the Flathead's water.**

The stream volunteer team of Flathead High School student Rebecca Welling and her father Mike conduct a chemical analysis of water in the Stillwater River near Kalispell.

A snapshot of the relative water quality of lakes in the Flathead watershed is provided by charts on page 45. Higher values of Chlorophyll *a* and Total Phosphorus levels suggest deteriorating water quality.

In 1998, the Commission published *Volunteer Monitor Program 1996-1997 Comprehensive Report*, a compilation of volunteer water quality data collected during that two year period. Copies are available at the Commission office. Additional information on the water quality of area lakes is available at the Commission's web site, **www.montanaweb.com/FBC/**.

Population and Land Use Trends

Monitoring the Basin's Growth and Development

Population growth and land use trends often have a strong correlation with the presence or lack of good water quality. Although point source pollution — untreated pollution from large industrial sites or municipal waste water systems — is not currently a problem in the Flathead Basin, nonpoint source pollution is of significant concern. The problem is exacerbated by a pattern of development where the greatest impacts have been on rural areas typically not served by community waste water treatment systems.

Both Lake and Flathead counties are among the fastest growing in the state, in large part because of the attraction of the watershed's scenic beauty and wealth of lakes and rivers. They continued to post significant population increases in the mid 1990s.

In 1997, the last year for which there are reliable estimates:

- **Lake County boasted a population of 25,341, or an increase of 20 percent since 1990. During that seven year period, Lake County experienced a net in-migration of 3,700, or 87 percent of the total population growth.**

- **Flathead County, meanwhile, had an estimated 71,707 residents in 1997, an increase of 21 percent since the beginning of the decade. The popularity of the area accounted for a net in-migration of 10,306 new residents, or 82 percent of the total population growth.**

Growth in both counties reflects the continuation of a trend of the conversion of farmland to non-farm, primarily residential and commercial development. Such indicators as septic permitting and subdivision lot creation point to continued high levels of growth, although the numbers for most of the indices in both counties are lower than in the mid 1990s, a peak period of the most recent growth cycle. Currently available information reflects that:

- **Lake County recorded 180 septic permits in 1998, up 14 percent from the previous year.**

- **Flathead County tallied 610 septic permits in 1998, an increase of 10 percent over the 554 permits issued in 1997. The county experienced a slight increase in subdivision lots created, up from 482 in 1996 to 490 in 1997. Another key growth indicator, residential construction, reflected a decline in recent years, from 738 total units in 1996 to 676 in 1997 and 589 in 1998.**

Improper construction activities may imperil water quality. Landowners and contractors alike should be knowledgeable of appropriate Best Management Practices and take the protection of water quality into account when designing projects.

Aquatic insects are an indicator of different levels of water quality. Participants in the Commission's Stream Volunteer Monitor Program inventory insects found in a local stream.

The North Fork of the Flathead River at the Montana, B.C. border is an important monitoring site. Inter-agency cooperation and Congressional funding has assured continued data collection in this international watershed.

Maintaining pristine water has become an important economic objective in the Flathead watershed. Clean water protects and enhances property values and benefits the region's important tourism-related economy.

Bilateral Cooperation

Working Colaboratively to Monitor and Protect Our Water

Since the late 1970s, when the prospect of an open pit coal mine project near the headwaters of the North Fork of the Flathead in southeastern British Columbia spurred the public's interest in water quality and planted the seeds for the creation in 1983 of the Flathead Basin Commission by the Montana Legislature, improving communications and coordination with British Columbia has been a Commission priority.

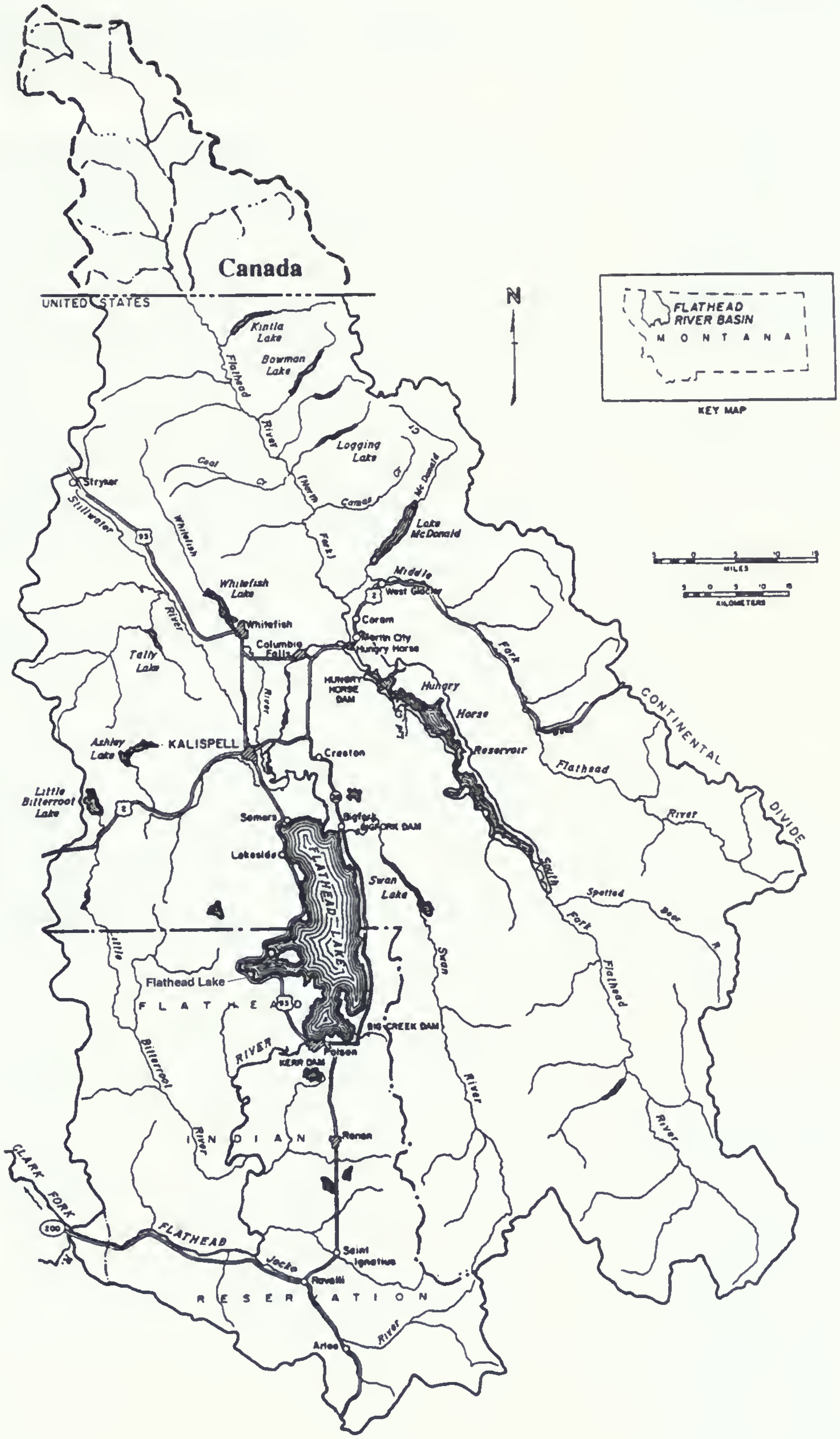
In recent years, thanks in large part to the "hands on" participation of our B.C. liaison, the Commission has been afforded numerous opportunities to work with British Columbia government agency representatives and citizens on matters relating to maintaining water quality and other environmental concerns in the headwaters of the North Fork, including:

- **Conducting information exchange meetings in both countries, where agency representatives and citizens from both are able to obtain up-to-date information on issues relating to the North Fork.**

- **Working with B.C. to reestablish the border monitor station that was destroyed by flooding in 1995. The Commission has helped coordinate an effort to obtain funding and other resources to get the much needed station up and operating. A $50,000 Congressional appropriation has been obtained and is being used with matching funds from MDNRC and the U.S. Geological Survey to rebuild the damaged cable way and reposition the data collection probe. The system is back on line, providing continuous discharge and elevation information. Work to install the new cable way is planned for 1999.**

- **Monitoring renewed mineral exploration activities in the B.C. Flathead, where three sites are under consideration for development as coal mines. The Commission is working closely with B.C. agency and mining company representatives to stay abreast of this issue, and will be afforded opportunities to review and comment on future mining proposals.**

- **Monitoring land use policies in the B.C. North Fork as the province's land use planning process evolves. When appropriate, the Commission will participate in public discussions of the East Kootenay land planning process as it relates to North Fork watershed concerns.**



Canada
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FLATHEAD RIVER BASIN
MONTANA
KEY MAP
MILES
KILOMETERS
Kintla Lake
Bowman Lake
Flathead
River
North
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Logging Lake
Coal Cr
Camas Cr
McDonald Cr
Lake McDonald
Stryker
Stillwater
River
Whitefish
Whitefish Lake
Whitefish
Middle
West Glacier
Coram
Martin City
Hungry Horse
Columbia Falls
Fork
Tally Lake
River
HUNGRY HORSE DAM
Hungry
Horse
Reservoir
CONTINENTAL DIVIDE
Flathead
River
Ashley Lake
KALISPELL
Creston
Little Bitterroot Lake
Somers
Bigfork
BIGFORK DAM
Lakeside
FLATHEAD LAKE
Swan
Lake
South
Fork
Spotted
Bear
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Flathead
Little
Bitterroot
River
Flathead Lake
FLATHEAD
RIVER
Polson
KERR DAM
BIG CREEK DAM
Swan
River
River
INDIAN
Ronan
CLARK FORK
FLATHEAD
Jocko
Saint Ignatius
Ravalli
RESERVATION
River
Arlee

Mike Lake monitors two bodies of water in the furthest reaches of the Flathead watershed, Lindbergh and Holland in the upper Swan River Basin.

Volunteer monitor Andy Apple mixes a water sample from Whitefish Lake that will be analyzed for the presence of Total Phosphorus. The higher the TP reading, the more serious the water quality problem. The water quality of Whitefish Lake is generally excellent.

1997 - 1998:
The Commission in Action

Education and Citizen Involvement Keys to Pollution Reduction

To make involvement in watershed issues possible for the greatest number of basin residents, the Commission conducts bi-monthly, day-long meetings in communities throughout the basin. By focusing agenda discussions on single, timely topics, the Commission is able to present a balanced program of accurate, up-to-the minute information on subjects ranging from cooperative resource management strategies with British Columbia to updates on water quality monitoring data. To afford local citizens an opportunity to participate in Commission discussions, meetings are conducted in Pablo, Polson, Bigfork, Kalispell, Whitefish, and Columbia Falls.

The Commission enhances it's outreach effort through its regularly published newsletter, *Basin Watch*, close cooperation with the region's print and electronic media, and through a variety of staff presentations to school classes and community groups.

In 1999, the Commission's website (**www.montanaweb.com/FBC/**) was inaugurated, allowing use of the internet to provide the public with information relating to Commission initiatives, water quality information, and pointers on how to reduce nonpoint source pollution. The site was provided as a public service by DigiSys, a Flathead area internet server, and designed through the technical assistance Marilyn Blair, Web Master of the USGS Glacier Field Station.

A Leadership Role in the Flathead Basin

To insure the highest level of coordination with agencies, organizations and the public and to carry out its recognized leadership role in water quality issues in the Flathead Basin, the Commission, through staff involvement, maintains ongoing involvement in a number of key organizations and processes, on both the local, regional and state level. Included are:

- **Montana Watershed Coordination Council, a multi-agency, Helena-based organization that addresses and coordinates watershed issues on a state-wide basis.**

- **Montana Watercourse Board of Advisors, which provides advice and guidance to enhance the effectiveness of educational programs initiated by the Montana Watercourse and Project WET Montana.**

- **Environmental Education Core Group, a northwest Montana-based effort that coordinates and advances the availability of responsible environmental and natural resource presentations in schools and for the community.**

- **Flathead Groundwater Coordinating Committee, an association of agency and private sector representatives that serves as the Commission's technical advisory committee for groundwater issues.**

Half Moon Lake volunteer monitor Terry Divoky draws a water sample for analysis for the presence of Chlorophyll a. Higher values suggest deteriorating water quality.

The Commission in Transition

Vice Chair David Mihalic succeeded Elna Darrow as Commission Chair, while Citizen Member Art Vail was chosen to serve as Vice Chair.

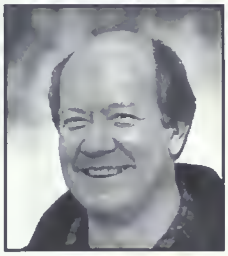
During the biennium, Flathead National Forest representative Rodd Richardson was transferred and was replaced by the new forest supervisor, Cathy Barbouletos. Julie Lapeyre replaced Glenn Marx as representative of the Governor's Office.

In accordance with the Commission's revised establishing legislation, agency representatives of the U.S. Army Corps of Engineers and the Bonneville Power Administration, Steven Foster and Gail Kuntz, were dropped from Commission membership while representatives from local conservation districts, Larry Van Rinsum of Flathead County and Alan Harriman of Lake County, were added.

Montana Power Company representative Robert O'Leary retired and was replaced by Jon Jourdonnais. Two other agency representatives, Van Jamison of MDEQ and Forrest Sanderson of Lake County Land Services, left their positions and have not to date been replaced. Two new citizen members were appointed by Governor Marc Racicot to replace Larry Wilson, whose term expired, and Bill Gregg, who resigned. They are Bruce Tutvedt, a Kalispell area agri-businessman and Gary Wicks, a Polson-based consultant.

The beauty and quality of the Flathead's waters are strongly linked to the region's image and its economic future.

Members of the Flathead Basin Commission



David Mihalic
Chair
Superintendent,
Glacier National Park

Art Vail
Vice Chair
Citizen member
Whitefish

Elna Darrow
Citizen Member
Bigfork

Paul Smiley
Citizen Member
Kalispell

Bruce Tutvedt
Citizen Member
Kalispell

Gary Wicks
Citizen Member
Polson

Marilyn Wood
Citizen Member
Bigfork

Dale Williams
County Commissioner
Flathead County

Larry Van Rinsum
Flathead County
Conservation District

Alan Harriman
Lake County
Conservation District

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Water Quality in the Flathead Basin

Why Monitoring Water Quality Is Critical

This section of the Biennial Report summarizes current information pertaining to water quality in the Flathead watershed. A primary goal of the Flathead Basin Commission is to identify existing or potential water quality problems and determine the sources of pollution. The information provided in this section assists the Commission in reaching that goal and provides agencies, the scientific community and the public with the best currently available information on water quality factors and trends in the Flathead watershed.

Scientists measure water quality using specialized techniques and sensitive indicators. They monitor the amount of various chemical substances dissolved and suspended in water. They also check on such things as the condition of stream bottoms and lake shores, streamflow, water temperature, turbidity, sediments, and the clarity of water.

Since fish live in water, the same variables strongly affect them. Therefore researchers evaluate fish habitat quality by looking at the size and amount of fine materials in streambeds and the emergence success of fry from gravels. They analyze fish populations by measuring the number and size of fish and by counting redds (nests built by spawning fish). They also monitor zooplankton (minute animals eaten by fish) to determine their effect on fish populations.

The Flathead River Basin Environmental Impact Study, conducted from 1979 through 1983, gathered and analyzed data related to various aspects of water quality. The study concluded that waters of the Basin were generally very pure, but the study also documented a trend of declining water quality attributable to both human-caused and natural activities.

Only through continuous, coordinated, and properly conducted monitoring will researchers, government agencies, and the public be able to identify sources of pollution and have the scientific information available to help develop effective and responsible means to reduce or eliminate such threats to the Flathead watershed's enviable high level of water quality.

How the Water Cycle Works

Most water is retained in the Flathead drainage system for only a short period of time. The highest mountains in the Basin may receive 70 inches or more of precipitation annually, whereas valleys typically receive between 15 and 20 inches a year. Once precipitation reaches mountainous terrain, some of it will run off, some will evaporate, some will enter vegetation, and the remainder will percolate through the soil into the groundwater system. Much of the groundwater will eventually emerge as a spring or enter directly into a creek or lake.

Water remains in ponds and lakes for varying amounts of time. In deep lakes, water stratifies during the summer as the upper layer is warmed by the sun and the lower layer remains cool. The denser colder water may remain confined to the lower levels of the lake until late in the season when all lake water is likely to achieve the same temperature and result in a mixing of the previously stratified portions.

Water entering Flathead Lake through its tributary rivers and streams will remain in the lake for about three years before being discharged into the lower Flathead River at Kerr Dam. During that time, most of the suspended sediments will have settled out of the water and onto the lakebed. The result is cleaner water at the discharge point than at the several points where river and stream water is introduced to the lake.

Factors Influencing Basin Water Quality

Freshwater ecology is the study of animals and plants in relation to their aquatic environment. Lakes and streams in the Flathead Basin support many biological species, and this diversity reflects the generally pristine condition of the Basin's waters.

While the aquatic species of the Basin are notably unique and diverse, individual populations are not normally abundant. The generally sterile nature of the Basin's waters and the relatively short growing season limit population growth. Surface waters of the Basin contain relatively few essential plant growth nutrients (such as nitrogen and phosphorus). The shortage of such nutrients naturally limits the production of algae and other plants, which in turn limits the populations of fish and other aquatic animals that feed on them.

The naturally low productivity of aquatic plants and animals in the Flathead Basin is a direct result of the Basin's high water quality. Increases in productivity may indicate declines in water quality. The addition of even small additions of nutrients may result in the population explosion of aquatic plants and may encourage the proliferation of undesirable fish species.

Both natural and human-caused events can lead to the deterioration of water quality. Virtually all land use activities ultimately affect water quality. The nutrients in atmospheric deposition — pollutants introduced into surface waters through dust, smoke, rain and snow — are also believed to be a significant contributor to water quality problems in the Basin. Other key factors that influence water quality include water flow, water temperature, turbidity and sedimentation, water chemistry, and microbiology.

The Law and Water Quality

Most recently,Total Maximum Daily Load (TMDL) legislation has become a guiding factor in addressing water quality issues in the state.

A wide variety of federal, state, tribal and local agencies have specific obligations to implement laws and apply regulations designed to protect water quality. A state permit system regulates point sources of pollution, such as discharges from municipal waste water treatment plants, while Best Management Practices (BMPs) are designed to control nonpoint sources of pollution (diffuse sources of pollutants resulting from natural occurrences and human activities over a relatively large area).

Laws and regulations that affect water quality in the Flathead Basin include:

- the Federal Clean Water Act and the Montana Water Quality Act (75-5-101(2)), ammended by the Montana Legislature in 1997, "to provide a comprehensive program for the prevention, abatement and control of water pollution..,"
- the Natural Streambed and Land Preservation Act (which regulates development activities taking place in streams and lakeshores),
- the Public Water Supply Law (which regulates activities with respect to their impact on water quality in watersheds used for public water supplies),
- the Sanitation in Subdivisions Act and the Subdivision and Platting Act (which together provide for state and local review of proposed subdivision),
- the Shoreline Protection Ordinance (which regulates certain structures, dredging, and filling below the high water mark on Flathead Lake and the Flathead River and its major tributaries within the Flathead Indian Reservation), and
- the Streamside Management Zone Law (which regulates timber harvesting activities adjacent to streams).

The Flathead Basin Commission supports agency enforcement of these regulations while encouraging agencies, corporate entities, and the public alike to assist in protecting water quality in the Basin through a variety of non-regulatory, voluntary means.

Flathead Lake and Its Tributaries

Water quality in Flathead Lake has been monitored continuously since 1977 by the Flathead Lake Biological Station. From 1977 to 1982 baseline limnological data were collected as a part of the Flathead River Basin Environmental Impact Study. Thereafter, the lake was monitored with funds obtained through a cooperative agreement between the Flathead Lake Biological Station and a consortium of management agencies. The Flathead Basin Commission coordinates the cooperative.

Monitoring results and basic limnological features of Flathead Lake have been reported in many biennial technical reports and journal publications (see references in "Monitoring Water Quality in Flathead Lake, Montana-1998 Progress Report," Ellis, et.al.) These studies have been funded by EPA and are the technical background for the development of a Total Maximum Daily Load (TMDL) allocation for the purpose of managing nutrient loads reaching Flathead Lake.

Interim Targets

Based on these studies the Flathead Basin Commission recommended and the Montana Department of Environmental Quality approved the following interim targets for the protection of water quality in Flathead Lake: 1) no increase in the biomass of lakeshore periphyton, 2) no measurable blooms of *Anabaena flos-aquae* (or other pollution algae), 3) no declining trend in oxygen concentrations in the hypolimnion, and 4) average annual concentrations of the following variables in the photic zone of the midlake deep site in Flathead Lake will not exceed the values indicated: primary production - 80 gC m^{-2} yr^{-1}, chlorophyll a - 1.0 µg/l, soluble reactive phosphorus - <0.5 µg/l, total phosphorus - 5.0 µg/l, total nitrogen - 95 µg/l, ammonium - <5.0 µg/l, nitrate + nitrite - 30 µg/l.

Progress report

The progress report pertains only to the primary objectives that are crucial to the monitoring of TMDL targets for Flathead Lake. The report summarizes the annual rate of primary production and mean concentrations of the TMDL target parameters (i.e., TP, SRP, TN, $NO_{2/3}$-N, Chl *a*) for the 1997 water year in comparison to long-term averages for the midlake deep site in Flathead Lake. Due to funding limitations, it was agreed that the Flathead Lake Biological Station would concentrate the available monies on maintaining a credible long-term record of the most critical variables. This required the deletion of some chemical and biological analyses (e.g., periphyton biomass; ammonium, chloride, silica, alkalinity and sulfate analyses; phytoplankton and zooplankton biomass and density; *Mysis relicta* density and distribution) and the deletion of more detailed data analyses (e.g., nutrient loading calculations and the correlation of response variables with loading estimates). In order to critically examine the long-term trends in water quality in Flathead Lake additional funds will be needed.

Study Sites

Monitoring sites discussed herein include:

- midlake deep (110 m depth) ca. 1 mile west of Yellow Bay Point in a pelagic area of Flathead Lake;
- Flathead Lake at the outlet sill near the Highway 93 bridge in Polson;
- Stoner Creek near Lakeside, a small lakeshore tributary stream;
- Ashley Creek below the Kalispell sewage treatment plant outfall, a small upstream tributary;
- Swan River in Bigfork, a large upstream tributary;
- Stillwater River in Evergreen, a large upstream tributary;
- Flathead River near Holt (Sportsmen Bridge), the primary upstream tributary;
- the bulk precipitation collector located at the Flathead Lake Biological Station on the east shore of the lake.

Results and discussion

Results of chemical analysis of samples collected from the tributary and bulk precipitation sites are shown in Table 1. Data are included for the funding period. A comparison of these means to the long-term means (i.e., 1997-1992) revealed substantially higher total nitrogen (TPN) values for the Stillwater River at Conrad Drive. Mean TPN for 1997-1998 was 375 µg/l compared to 293 µg/l for the 1977-1992 period of record. A comparison of nitrate nitrogen (NO_3-N) data from 1977-1992 to nitrate plus nitrite ($NO_{2/3}$-N) data from 1997-1998 indicate much higher levels of inorganic nitrogen in the Stillwater River during the last sampling period; the mean $NO_{2/3}$-N for 1997-1998 was 280 µg/l compared to a mean of 164 µg/l NO_3-N for the 1977-1992 period. Although NO_2-N data were not reported for the Stillwater River for the 1977-1992 period, additional data indicate that >98% of the nitrogen in $NO_{2/3}$-N is in the form of NO_3-N. The maximum $NO_{2/3}$-N value of 600 µg/l that was measured during the 1997-1998 period exceeded the range of values observed for the Stillwater River (i.e., maximum value for the 1977-1992 period was 518 µg/l NO_3-N). The mean concentration of $NO_{2/3}$-N was also higher in the mainstem Flathead River at Holt in 1997-1998 than for the 1977- 1992 period (i.e., 81 µg/l $NO_{2/3}$-N compared to 69 µg/l NO_3-N, respectively).

During the 1997 water year, abundant snow accumulation at low elevations resulted in flooding of many of the lowland tributaries that likely increased the transport of materials and associated nutrients and carbon into the streams and rivers. Stream water inundated farm fields, grazing lands, ranchette developments and other semi-urban areas in close proximity to the streams. Although nutrient concentrations in Ashley Creek were lower than the long-term means reported in 1992,

Table 1. Mean, minimum and maximum values for chemical analysis of grab water samples at five tributary sites and the outlet site for Flathead Lake from July 1, 1997 to September 1, 1998. Results from the analysis of bulk precipitation samples collected at the Flathead Lake Biological Station point from July 1, 1997 to September 1, 1998 are also presented. See Table 1 for description of variable abbreviations.

site		pH units	*Cl (mg/l)	*SiO_2 (mg/l)	*SO_4 (mg/l)	*DIC (mg/l)	DOC (mg/l)	NDOC (mg/l)	TURB (NTU)	**TSS (mg/l)
Ashley Creek below Kalispell STP	mean			11.2	9.37	38.7	8.3	1.7	16.7	30.6
	min			5.3	7.28	36.1	2.7	0.8	3.8	5.6
	max			19.1	11.70	40.8	13.6	2.9	40.3	65.4
Flathead River at Holt	mean			5.2	3.35	16.5	2.7	0.4	17.8	29.0
	min			4.4	2.45	10.1	1.4	0.1	1.6	2.8
	max			5.9	4.29	19.4	8.2	1.9	135.0	142.5
Stillwater River at Conrad Drive	mean			9.9	3.26	27.3	3.1	0.5	11.5	20.3
	min			8.7	2.46	24.2	2.1	0.2	2.7	3.1
	max			10.7	3.95	30.1	5.9	1.0	35.2	38.2
Stoner Creek at Flathead Lake	mean			18.7	3.64	39.3	4.3	0.9	7.1	20.6
	min			8.4	3.07	35.7	0.9	0.1	1.0	2.7
	max			36.1	4.36	41.4	9.3	4.0	41.0	72.2
Swan River at Bigfork	mean			7.0	1.31	17.3	2.4	0.2	1.3	1.3
	min			5.8	1.05	14.7	1.2	0.1	0.7	<0.5
	max			7.8	1.49	19.5	4.2	0.4	2.1	2.4
Bulk Precipitation at Yellow Bay point	mean	5.2	0.11	<0.2	0.40					
	min	4.7	<0.04	<0.2	0.08					
	max	5.6	0.28	<0.2	0.77					
Flathead Lake outlet at Polson	mean			6.3	2.76	17.6	2.0	0.3	1.3	1.3
	min			5.1	2.52	15.0	0.7	0.2	0.6	0.9
	max			8.1	3.11	20.9	3.0	0.3	3.3	1.8

Table 1. (continued)

site		TPN (µg/l)	*NH_4-N (µg/l)	$NO_{2/3}$-N (µg/l)	TP (µg/l)	SP (µg/l)	SRP (µg/l)
Ashley Creek below Kalispell STP	mean	1154	50	575	80.8	44.3	25.5
	min	867	<5	54	42.2	22.5	9.4
	max	1924	100	1246	119.2	85.6	65.0
Flathead River at Holt	mean	161	8	81	14.3	3.1	1.0
	min	77	<5	30	5.2	1.7	<0.3
	max	406	24	122	56.1	5.3	3.0
Stillwater River at Conrad Drive	mean	375	19	280	15.9	5.2	1.4
	min	184	<5	72	7.4	3.4	<0.3
	max	726	62	600	36.8	7.8	2.9
Stoner Creek at Flathead Lake	mean	163	6	20	24.6	14.7	8.6
	min	81	<5	5	12.0	9.3	4.8
	max	392	8	80	71.1	20.2	12.7
Swan River at Bigfork	mean	94	5	21	6.1	2.9	0.7
	min	54	<5	5	4.5	2.1	<0.3
	max	142	6	37	7.8	4.6	1.0
Bulk Precipitation at Yellow Bay point	mean	454	198	206	14.5		1.7
	min	106	39	38	2.3		<0.3
	max	962	528	584	33.7		6.0
Flathead Lake outlet at Polson	mean	102	5	25	5.4	2.7	0.8
	min	81	<5	<0.6	4.0	1.7	<0.3
	max	125	6	57	6.9	4.4	1.2

* Analysis discontinued for some sites due to lack of funding after March 1, 1998.
** Analysis only run during spring run-off (i.e., March through June)

the long-term average for Ashley Creek included very high values associated with discharges from the Kalispell Sewage Treatment Plant before it was upgraded to tertiary treatment. Additional analysis of the Ashley Creek database in which only that period after improved sewage treatment is included, may reveal a similar pattern of high nutrient concentrations during the 1997 water year for Ashley Creek. Indeed, mean and maximum concentrations for all nutrients in Ashley Creek exceeded values observed in all the other tributaries (see Table 1).

In general, mean concentrations in Stoner Creek and the Swan River were similar to the long-term means reported in 1992 (see Table 1). Total phosphorus values in Stoner Creek remain quite high compared to other streams in the Flathead Basin. The maximum of 71 μg/l recorded during the 1997-1998 sampling was close to the upper end of the long-term range for Stoner Creek (i.e., 77 μg/l for 1985-1992 period). Additional work is needed in the Stoner Creek catchment to determine the source of relatively high phosphorus and total nitrogen concentrations. In addition to the primary tributary sites, approximately 43 streams (perennial and intermittent) flow directly into Flathead Lake and little is known about the transport of nutrients from these sites. Although the flow is small in comparison to the major tributaries that are regularly monitored, localized impacts may occur, particularly in areas of reduced circulation.

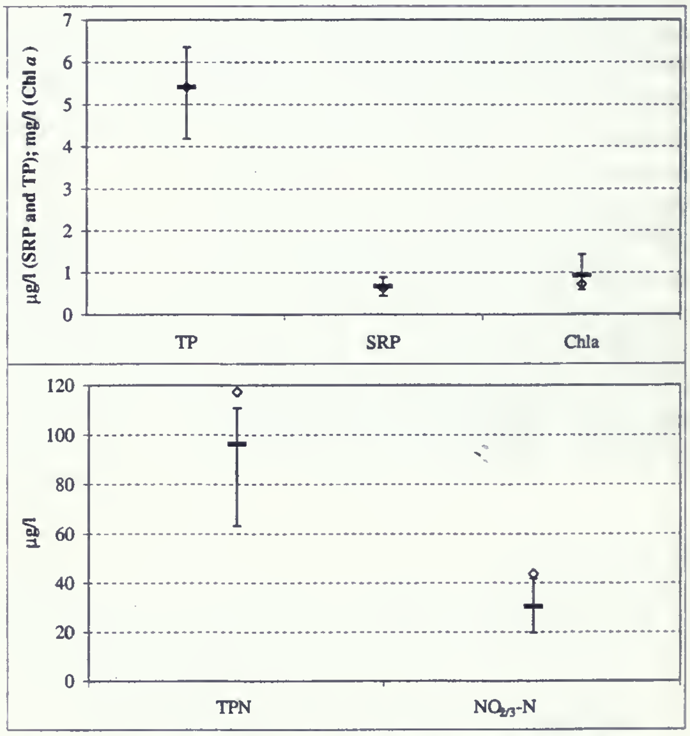


Figure 1. Long-term mean (thick bar) and range of means (thin bars) for nutrient and chlorophyll *a* concentrations of 0-30 m integrated samples collected from 1987 to 1996 at the midlake deep site on Flathead Lake. Means were calculated for each water year (i.e., October 1 - September 30). Mean concentrations for the 1997 water year, October 1, 1996 to September 30, 1997, (diamonds) are also presented for comparison.

Nutrient concentrations in bulk precipitation samples were low compared to previous years, particularly phosphorus (see Table 1). Reduced concentrations of nutrients in 1997-1998 could be due to many factors such as a change in weather patterns that reduce or eliminate air inversions in the Flathead valley, a reduction in wildfires and slash burning, or less road dust due to a wetter summer and/or fall.

The higher inorganic nitrogen concentrations that were measured in the Stillwater River and the mainstem Flathead River were also mirrored at the midlake deep site in Flathead Lake and the lake outlet site at Polson (Tables 1 and 2, Figure 1). For the TMDL target variables, mean concentrations were determined for the 1997 water year (October 1, 1996 - September 30, 1997) for 30 to 36 m integrated samples collected from the midlake deep site in Flathead Lake (Figure 1). Means for the 1997 water year were compared to water year means for the period of record (i.e., integrated samples collected from 1987-1996). The means for water year 1997 for both TPN and $NO_{2/3}$-N were outside the range of 1987-1996 means (Figure 1). Concentrations of both nitrogen variables were also higher than the TMDL targets for midlake deep (Table 3). Although the calculation of nutrient loads to Flathead Lake was not a part of this study, it is likely that nitrogen loading to the lake was well above average.

The Montana Department of Environmental Quality selected for monitoring only those water quality variables that they deemed crucial to the TMDL process. Although the Flathead Lake Biologi-

cal Station was not funded to measure ammonium nitrogen (NH_4-N), they assumed the cost throughout the 1997 water year, but due to inadequate funding, analyses were discontinued on March 1, 1998. The mean concentration of NH_4-N at the midlake deep site for the 1997 water year was 6.4 µg/l, which was slightly higher than the TMDL interim target of 5.0 µg/l. On June 13, 1997, during the runoff period, NH_4-N concentrations of the integrated sample and the 90 m sample were the highest ever measured (i.e., 14.8 µg/l and 20.2 µg/l, respectively). The 5 m sample was 7.2 µg/l. These values are quite high because NH_4-N is usually very close to or below the detection limit (i.e., < 5.0 µg/l) at the midlake deep site. Concentrations of both phosphorus variables in 0-30 m samples from the midlake deep site were very close to the long-term means and the TMDL interim targets, while chlorophyll *a* was somewhat lower than the long-term mean and target concentrations (Figure 1 and Table 3).

Mean annual pelagic primary productivity in Flathead Lake for the 1997 water year was 101 gC m^{-2} yr^{-1} (Figure 2). Primary productivity in 1997 was higher than estimates for the previous 4 years and almost identical to the annual mean for 1992. The 1997 mean exceeded the TMDL interim target by 21 gC m^{-2} yr^{-1} (Table 3). Our long-term record of primary productivity in Flathead Lake is a robust indicator of water quality that is strongly influenced by external nutrient loads . Elevated levels of nitrogen at midlake deep suggest that nitrogen loading to the lake was probably high in 1997. Experiments strongly support the conclusion that growth of algae in Flathead Lake is controlled by nitrogen and phosphorus supply. But it is important to remember that under certain conditions, food web changes may also influence primary production by altering the density of organisms that cycle these nutrients within the lake. The annual survey of *Mysis* in 1997 revealed a mean density of 68 organisms/m^2, the highest density recorded since the major peaks in 1986 and 1987. Clearly alterations in the lake food web will continue as *Mysis* densities fluctuate so dramatically. Experiments have shown that if nutrient levels in Flathead Lake increase, organisms such as *Mysis* will become more important in regulating primary production; but, at current nutrient levels, nitrogen and phosphorus appear to be more important in controlling the algal community in the lake .

The Flathead Lake Biological Station continued to monitor oxygen levels at the Ross Deep site in Big Arm Bay although funding was not available. The water column profile of oxygen at Ross Deep

Table 2. Mean, minimum and maximum values for chemical analysis of integrated (0-30 m) and discrete grab (5 m and 90 m) samples collected from July 1, 1997 to September 1, 1998 at the midlake deep site (MLD) on Flathead Lake. See Table 1 for description of variable abbreviations.

site		*ALK (mg/l $CaCO_3$)	*SiO_2 (mg/l)	*SO_4 (mg/l)	DIC (mg/l)	DOC (mg/l)	NDOC (mg/l)	TURB (NTU)	**TSS (mg/l)
MLD 0-30 m	mean	90.7	4.7	2.81	18.8	1.9	0.2	0.9	0.9
	min	88.5	0.2	2.70	15.9	1.6	0.1	0.4	0.5
	max	93.5	6.1	2.96	21.4	2.5	0.2	3.0	1.6
MLD 5 m	mean	88.0	5.2	2.73	18.9	2.0	0.2	0.7	0.8
	min	84.0	4.8	2.51	16.8	1.6	0.1	0.4	<0.5
	max	92.8	5.8	2.96	21.4	3.2	0.3	2.1	1.3
MLD 90 m	mean	92.9	5.9	3.05	19.2	2.3	0.1	1.0	0.8
	min	86.2	5.7	2.90	16.3	1.4	0.1	0.4	<0.5
	max	100.8	6.1	3.10	22.1	6.1	0.1	2.1	1.8

site		TPN (µg/l)	*NH_4-N (µg/l)	$NO_{2/3}$-N (µg/l)	TP (µg/l)	SP (µg/l)	SRP (µg/l)	CHL *a* (µg/l)
MLD 0-30 m	mean	107	<5.0	47.6	5.3	2.9	0.6	0.787
	min	83	<5.0	19.6	4.4	2.0	0.3	0.476
	max	124	<5.0	62.2	6.7	4.0	1.5	1.546
MLD 5 m	mean	98	5.8	33.3	5.4	3.1	0.8	
	min	66	<5.0	0.6	4.0	2.1	0.3	
	max	134	9.7	58.7	6.9	4.4	2.1	
MLD 90 m	mean	115	<5.0	71.7	5.0	3.2	0.7	
	min	100	<5.0	59.0	4.1	2.1	<0.3	
	max	140	<5.0	89.0	8.5	4.5	1.0	

* Analysis discontinued for some sites due to lack of funding after March 1, 1998.
** Analysis only run during plume from spring run-off (i.e., April through July)

Table 3. Interim numeric TMDL targets for the midlake deep site (0–30 m integrated water column) in Flathead Lake and mean concentrations of those target variables for the 1997 water year. All nutrient and chlorophyll *a* concentrations are in µg/l and primary productivity is given in gC m^{-2} yr^{-1}.

target variable	TMDL target value	mean concentration for 1997 water year
total nitrogen (TPN)	95	117
nitrate + nitrite nitrogen ($NO_{2/3}$-N)	30	44
ammonium nitrogen (NH_4-N)	5.0	6.4
total phosphorus (TP)	5.0	5.4
soluble reactive phosphorus (SRP)	0.5	0.6
chlorophyll *a* (Chl *a*)	1.0	0.7
primary productivity	80	101

on 19 August, 1997 showed gradual depletion of oxygen with depth but minimum values were not as low as in previous years; % saturation of oxygen decreased from 10 1. 1 % at the surface to 70.6 % at the bottom. The minimum concentration at the bottom was 8.15 mg/l. Dissolved oxygen concentrations improved by late September, with bottom values of 9.50 mg/l or 82.8% saturation. The TMDL interim target that recommends no oxygen depletion in the hypolimnion for the midlake deep site, should be revised to indicate that the measurement should occur during the entire period of thermal stratification. It is during the period of thermal stratification that depletion of oxygen in bottom waters is a concern, as mixing from oxygenated surface waters is limited due to the thermocline. Profiles of dissolved oxygen at the midlake deep site during the late summer and fall of 1997 indicated that the water column was continually well oxygenated. On occasion, minor reductions in dissolved oxygen were observed near the bottom. For example, on 25 September, 1997 dissolved oxygen concentrations were about 9.6- 9.8 mg/l from 30 m down to 80 m, then at 90 m (>10 m above the bottom), dissolved oxygen dropped to 9.0 mg/l. Additional near-bottom measurements will be made in the future to better delineate oxygen concentrations close to the sediment-water interface.

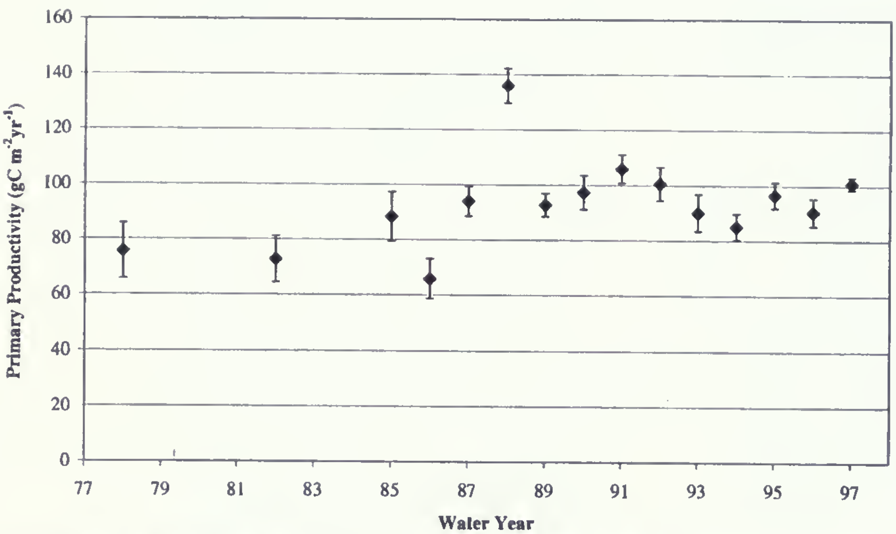


Figure 2. Mean annual pelagic primary productivity (gC $m^{2}yr^{-1}$) at the midlake deep site for Flathead Lake from 1978 to 1997. Bars represent minimum and maximum yearly estimates.

The pollution algae, *Anabaena flos-aquae*, was observed as a floating scum in the area of the dock at the Flathead Lake Biological Station on 31 July 1997 and a sample was obtained for density and biomass analysis. Surface algal scum was not observed at the midlake deep site during the 1997 water year but surface samples collected during the late summer have not been analyzed. Funds were not available for biomass and density analysis, but the samples have been archived and can be counted at a future date. The TMDL interim targets recommend no measurable blooms of *Anabaena flos-aquae* (or other pollution algae) at the midlake deep site. The TMDL interim targets also state that there shall be no increase in the biomass of lakeshore periphyton, but unfortunately funds were not available for such determinations.

Given current, inadequate funding the Flathead Lake Biological Station is unable to assess all interim TMDL targets. Of those targets we were able to examine, $NO_{2/3}$ -N and TPN concentrations were definitely in exceedence of the targets established for the protection of water quality in Flathead Lake.

Headwater Streams in the Flathead National Forest

One of the key issues in restoring water quality of the impaired waters and protecting water quality elsewhere in the basin is the influence that forest roads and timber harvest may have on water quality.

For well over two decades, managers and scientists have attempted to examine this issue by sampling an array of streams draining small watersheds with varying harvest histories. This effort has been called the "Headwaters Monitoring Project" to distinguish it from efforts to quantify and control water pollution in the non-forested portions of the Flathead Basin. Unfortunately, the "headwaters" study has been inconsistent, with sampling effort changing from year to year and site to site as dictated by poor funding.

Nonetheless, Hauer and Hill examined the available data through 1996 and concluded that water quality was generally higher in watersheds with no forest harvest or roads than in watersheds that had a significant harvest and road legacy. However, the study sites encompassed a wide range of lithologies, sampling frequencies and harvest histories varied and the utility of the study was limited by lack of specificity to particular harvest practices.

Here we add to the accumulating database concerning forest management effects on water quality in the Flathead Basin. As in previous work, data collection was limited and watersheds were not selected specifically to clearly resolve the issue (i.e., more comparable sites may have existed but the funding was limited and forest managers were reluctant to discontinue the long-term monitoring sites). However, the data were sufficient for some meaningful comparisons of water quality in relation to intensity of forest harvest activity in the few watersheds examined. These watersheds drain the same lithology (Whitefish Range) and are located in the same general area, supporting our rationale for comparing water quality in relation to timber harvest.

In addition to the long-term analyses, annual synoptic surveys of another watershed were conducted in an effort to relate longitudinal changes in the water quality variables to forest harvest and other attributes of the watershed.

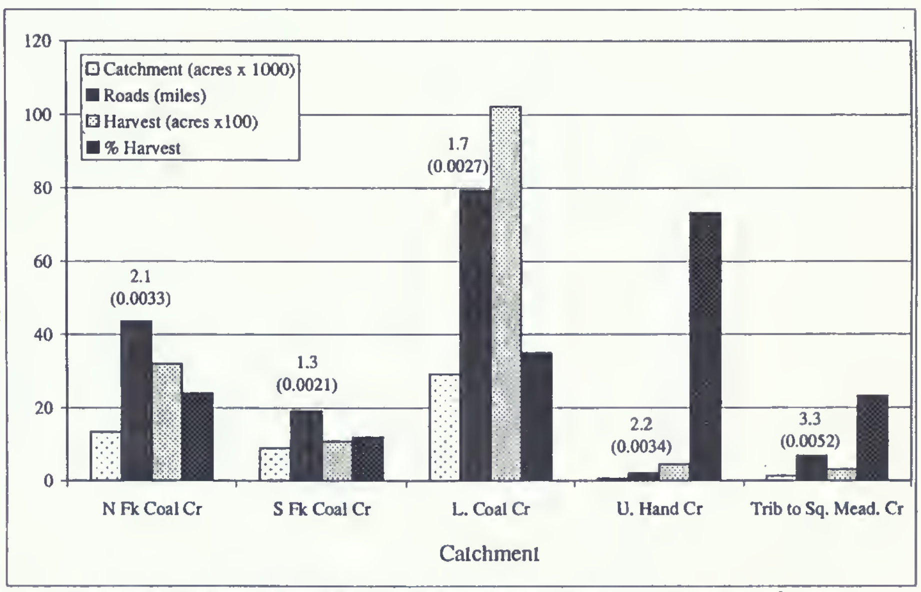


Figure 1. Catchment area, road miles, harvest area and percent catchment harvested through 1997. Road miles per mile^2 (per acre) of the catchment are shown above each road histogram.

Study Sites

Coal Creek (N. Fork Flathead River)

Three sites on Coal Creek were monitored (N. Fork, S. Fork and Lower Coal at Deadhorse Bridge) in 1997, which added to data collected in 1996. From 12% - 35% of the Coal Creek watershed upstream of the lower site (i.e., including areas on the North and South Forks of Coal Creek) was roaded and harvested since the early 1950's (see Figure 1). Some of the older harvest was accomplished with jammer roads and skid trails that were located in riparian zones adjacent to the streams.

Some or all of the compacted areas resulting from these early practices may still be affecting the hydrologic function of the stream by changing runoff patterns and timing. Forest management activities during the last 5 years has been limited to a small salvage timber sale, 2 miles of road obliteration in the south Coal drainage and road blading from the Lower Coal site to the North Fork of Coal Creek site.

Tributary of Squaw Meadow Creek (Stillwater River)

Water quality and discharge at this site have been monitored by the United States Forest Service (USFS) since 1982, but sampling was often concentrated during the runoff period. In 1997, we initiated more routine, seasonal water quality sampling at this site. As of this report, approximately 23% of the catchment was harvested and road miles per square mile (3.3) were higher than for the other monitoring sites (Figure 1). Most of the harvest occurred in 1985. About 1.5 miles of road were reclaimed in 1995. No harvest occurred in 1997. Also, cattle grazing has been permitted for many years in this small watershed.

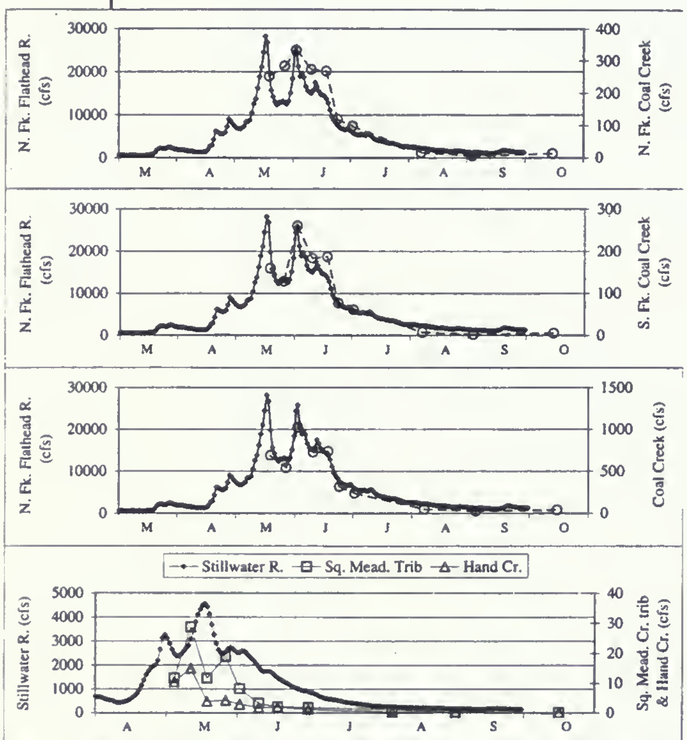


Figure 2. Comparisons of the continuous USGS discharge guage on the North Fork Flathead River near Columbia Falls, Montana (solid diamonds) to discharge measures from the Coal Creek sites (open circles) at the time of sample collection in 1997. Also shown is the comparison of the continuous USGS discharge guage on the Stillwater River near Whitefish, Montana (solid diamonds) to the discharge measures from the tributary to Squaw Meadow Creek (open squares) and Hand Creek (open triangles) at the time of sample collection in 1997.

Hand Creek (Stillwater River)

Hand Creek (near the Snotel site) has been continuously monitored by the USFS since 1981. This site was originally intended to be an unharvested control for studying harvest effects on water quality in the Flathead Basin. However, a wildfire (Little Wolf) burned the entire Hand Creek catchment in August and September of 1994. A host of management activities occurred upstream of this site after the fire including salvage logging and harvest of beetle infested spruce within the riparian area; however, this catchment was heavily harvested prior to the fire. By 1997, over 70% of the catchment was roaded and harvested (Figure 1).

Big Creek Synoptics (N. Fork Flathead River)

The Big Creek catchment was sampled synoptically by the USFS to investigate the influence of a wetland and several timber management areas on water quality of the streams. The long-term monitoring site on Big Creek should reflect the cumulative effects of forest management activities in the catchment. Details of the Big Fork Synoptics may be found in the full report (see Science Report Bibliography, Page 48). Included are sections on wetland influence on water quality, and harvest-no harvest comparisons on two tributaries of Hallowat Creek and Kletomas Creek. Also included is a section on a harvest-no-harvest comparison of two high altitude tributaries associated with the Big Mountain Ski Resort.

Results and Discussion

Watershed Comparisons Using Time Series Data

In 1997, USFS personnel were unable to sample the headwater streams until May, which was after the primary peak in spring runoff for the North Fork of the Flathead River (see Figure 2). Close correlations between Coal Creek discharge (South Fork and Deadhorse sites only) and North Fork of

the Flathead River discharge indicated that the Coal Creek sites peaked before they were sampled. Thus, maximum nutrient, sediment and carbon concentrations for 1997 were not measured and loads were underestimated. Although Coal Creek discharge could be estimated for the entire period using the North Fork of the Flathead River correlation, lack of nutrient data during the rising limb and peak of the hydrograph precluded estimation of loading for the entire water year. Discharge in Hand or the Tributary to Squaw Meadow Creek did not correlate with discharge values from the closest continuous stream gauge (USGS gauge at Stillwater River near Whitefish, see Figure 2). However, continuous stage data for Hand Creek indicated that both sites were sampled on the rising limb of the hydrograph.

Coal Creek Watershed

Similar seasonal patterns in sediment and solute concentrations were observed in 1997 as compared to 1996. As stream discharge increased during the snowmelt period, the concentration of the fine particles being transported by the stream (i.e., total suspended solids, TSS) increased (Figure 3a). Since higher flows are more erosive, TSS often was closely correlated with stream discharge. Total suspended solids and turbidity were highest and most variable at lower Coal (Deadhorse Bridge) and the North Fork of Coal Creek site both years (Figure 3a). All of the Coal Creek sites carried more suspended solids (TSS) than the other sites.

A fairly good correlation was obtained between total phosphorus (TP) and TSS ($r^2 = 0.70$), so seasonal patterns were similar. These data confirm that much of the phosphorus entering Coal Creek was associated with sediment particles (occluded). As the concentration of occluded P increases, soluble forms of phosphorus often increase as they are released from the sediment particles, depending upon stream chemistry. SRP concentrations in the Coal Creek catchment did not vary much with increased discharge. However, small increases in SRP were coincident with peaks in TP in the South Fork in 1997, perhaps a result of phosphorus release from sediments (Figure 3b).

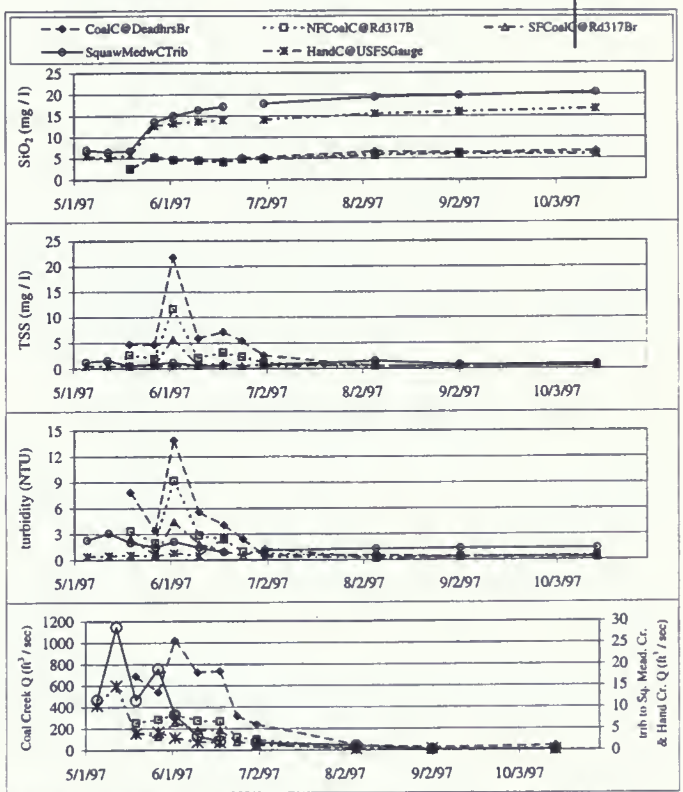


Figure 3a. Concentrations of silica (SiO_2), total suspended solids (TSS), turbidity and discharge for each of the headwater monitoring streams, 1997.

Particulate carbon (non-dissolved organic carbon, NDOC) also peaked in Coal Creek during peak discharge (Figure 3c). Sources of NDOC to the stream include terrestrial input during rain or snowmelt events and scouring of plant and animal communities within the streambed.

Ammonium concentrations were generally low. The cause of the relatively high ammonium value in early June in the South Fork (Figure 3c) is unknown, though may be related to the leaching characteristics of soils in the Coal Creek catchment.

The seasonal pattern in nitrate plus nitrite nitrogen ($NO_{2/3}$-N) in the Coal Creek catchment was similar in 1996 and 1997 (Figure 3c). The pattern of relatively high nitrate concentrations during base flow and lower concentrations during peak flows suggested that groundwater may be a significant source of water to the catchment. Groundwater is typically higher in nitrate than surface waters. During base flow, if the groundwater contribution to the stream is high (which is typically the case in the Flathead Basin), one would expect higher nitrate concentrations. Thus, during spring snowmelt, nitrate concentrations would be diluted. In a comparison of nitrate and total nitrogen concentrations (TPN) in the Coal Creek catchment we found that more organic nitrogen (i.e., TPN - ($NO_{2/3}$-N + NH_4-

N)) was carried by the stream during the runoff period. Terrestrial inputs during snowmelt and streambed scouring are likely sources of the increased organic nitrogen.

Nutrient (N and P forms) and sediment loading per unit catchment area reflected differences in discharge per unit area for most variables (Figure 4). In 1996, the notable exception was the TSS load per unit area for lower Coal Creek and the North Fork site. Although the water yield per catchment area was greater in the South Fork, the North Fork and lower Coal Creek transported more sediment per unit area. Soils in the Coal Creek catchment are more erodable due to the texture and overall lack of cohesion. Streams running through these areas would be expected to have a higher concentration of TSS and be more prone to increased channel erosion with increased levels of forest management (i.e., increased water yield and peak flows). In 1997, TP, TSS and NDOC loading per unit catchment area were considerably higher in lower Coal Creek than the other two sites while water yield per unit area was not that much higher in comparison. Similar results were reported for 1994 and 1995. In that study, baseline water quality data was obtained for Gorge Creek, a large wilderness catchment on the S. Fork Flathead River. Gorge Creek had the highest water yield, but had comparatively low TSS and TP loads. In contrast, lower Coal Creek, the similarly sized drainage in the site array, with nearly 80 miles of roads and 5000 acres of timber harvest (i.e., about 17% of drainage area), had over twice the TSS load and nearly 3X the TP load per area as Gorge Creek in 1994-95. Unfortunately, sampling of Gorge Creek was not continued in 1996 and 1997 due to lack of monitoring funds, therefore, a paired watershed comparison was not possible in the same water years.

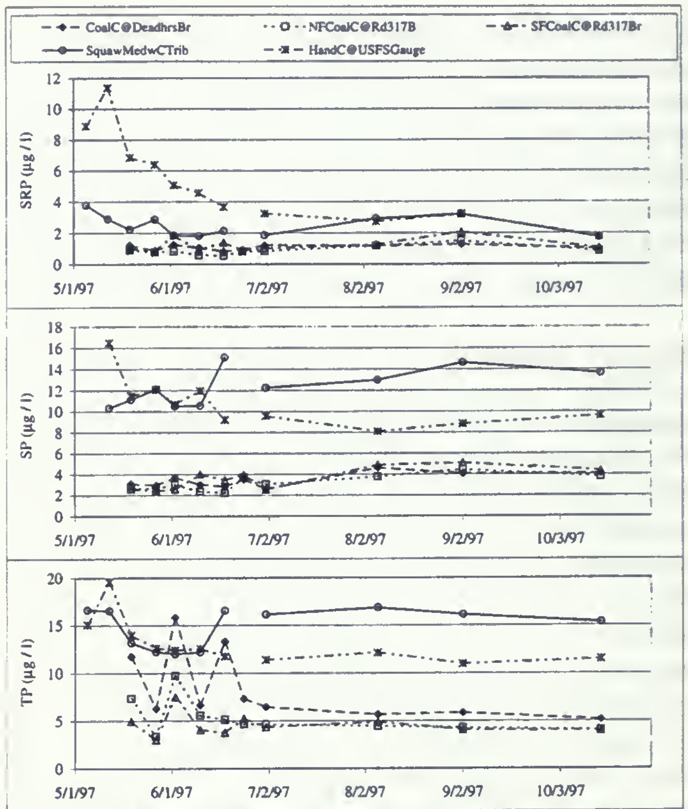


Figure 3b. Concentrations of soluble reactive phosphorus (SRP), soluble phosphorus (SP) and total phosphorus (TP) for each of the headwater monitoring streams, 1997.

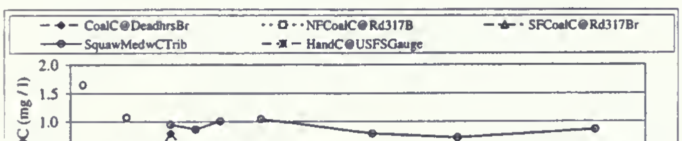


Figure 3c. Concentrations of non-dissolved organic carbon (NDOC), ammonium (NH_4-N), nitrate plus nitrite nitrogen ($NO_{2/3}$-N) and total persulfate nitrogen (TPN) for each of the headwater monitoring streams, 1997.

Particulate carbon (i.e., NDOC) was measured at the monitoring sites for the first time in 1997 (Figure 3c and 5). The disproportionately higher loading of NDOC per unit catchment area in lower Coal Creek as compared to the other Coal Creek sites is of interest. The

increase in carbon may be partially explained by the transition from predominantly coniferous vegetation in the riparian zone of the upper tributaries to deciduous vegetation in the wider, wetted riparian area of Lower Coal Creek. Whether the deciduous leaf fall could account for the 2-fold difference in NDOC loading per acre is unknown. A quantitative comparison of the percent of deciduous versus coniferous cover in the riparian areas of each of the monitoring streams may provide some insight into the potential contribution of particulate carbon from leaf fall. A 1995 study concluded that the oxygen deficit in Swan Lake appeared to be driven by allochthonous (originating outside the lake) carbon inputs and that streams in areas recently logged may have provided a substantial proportion of the organic carbon that was decomposed in the lake. Research showed that sedimentation rates in Swan Lake were closely correlated with logging activities within the catchment and that allochthonous input of organic matter could be a contributing factor to the observed oxygen deficit. Continued monitoring of particulate carbon in headwater streams appears warranted given the potential impacts of accelerated loading of organic matter to downstream lakes.

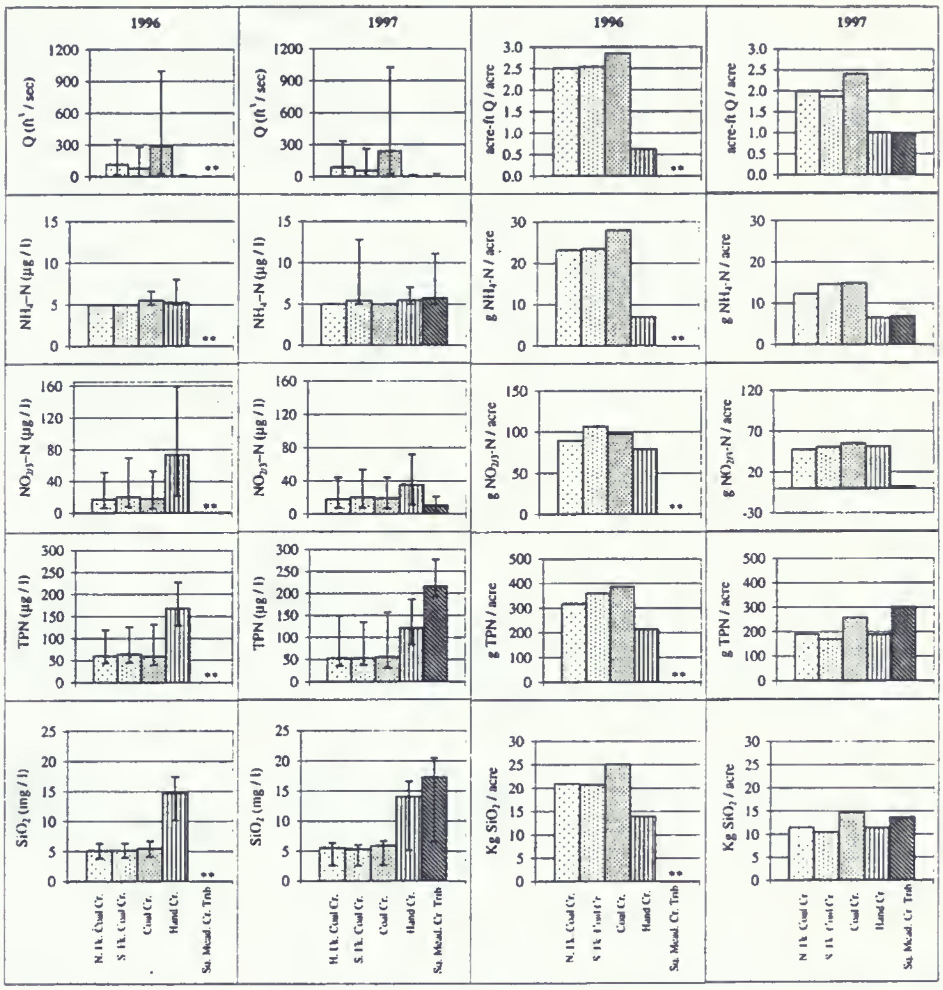


Figure 4. Mean discharge (Q) and concentration of amonium nitrogen (NH_4-N), nitrite plus nitrate nitrogen ($NO_{2/3}$-N), total nitrogen (TPN), and silica (SiO_2) for the 1996 and 1997 project periods (left series). Bars depict range of values for each period. Water yield and total load per acre of the catchment is also given (right series).

** Site not sampled in 1996

<u>Upper Hand Creek Watershed</u>

Seasonal patterns in SiO_2, TPN, TP, SP, TSS and turbidity were similar to those observed in the tributary to Squaw Meadow Creek (Figures 3a, b, c) with a few minor exceptions. NH_4-N concentrations remained at or near the detection limit. Because NH_4-N is the most available form of nitrogen for uptake by algae, it is not surprising to see consistently low values. Typically the silica content of river waters tends to be remarkably uniform and shows little response to change in discharge rates. However, the relatively low concentrations of SiO_2 in spring and the rapid rise during runoff suggested that the streambed community may have been composed of actively growing diatoms in early spring (i.e., diatoms rapidly remove silica from the water) or that other abiological buffering mechanisms were taking place. The major source of silica is from the degradation of aluminosilicate minerals, thus the higher levels found in Hand Creek in comparison to Coal Creek likely also relate to differences in catchment geology (i.e., more clay soils in the Hand Creek catchment).

The temporal patterns of $NO_{2/3}$-N and SRP showed the most obvious differences. The drop in $NO_{2/3}$-N as runoff progressed followed the pattern observed for Coal Creek, with the lowest values measured in late spring. But as discharge continued to decline, $NO_{2/3}$-N increased through late summer and fall to a peak >2X that of all other monitoring sites. Whether groundwater contributions could explain the relatively high $NO_{2/3}$-N concentrations is unknown. Studies to determine the vertical movement of water in the streambed and lateral movement of water to the stream channel would provide useful information about the extent of groundwater inputs. SRP concentrations were very high in Upper Hand Creek during early runoff in comparison to the other monitoring streams and remained elevated throughout most of the study period. The SRP probably did not arise from desorption from sediment particles suspended during runoff, as TSS concentrations were relatively low.

In 1996, mean nutrient and silica concentrations in Hand Creek were much higher than the Coal Creek sites, with the exception of NH_4-N concentrations, which were similar (Figures 4 and 5). Mean $NO_{2/3}$-N was 4X higher in Hand Creek than in Coal Creek, while TPN was 3X, SiO_2 3X, SP >2X, SRP 4X and TP >1.5X higher. Similar comparisons were evident in 1997 for the various forms of phosphorus and SiO_2, but $NO_{2/3}$-N and TPN were somewhat lower in 1997 than in 1996.

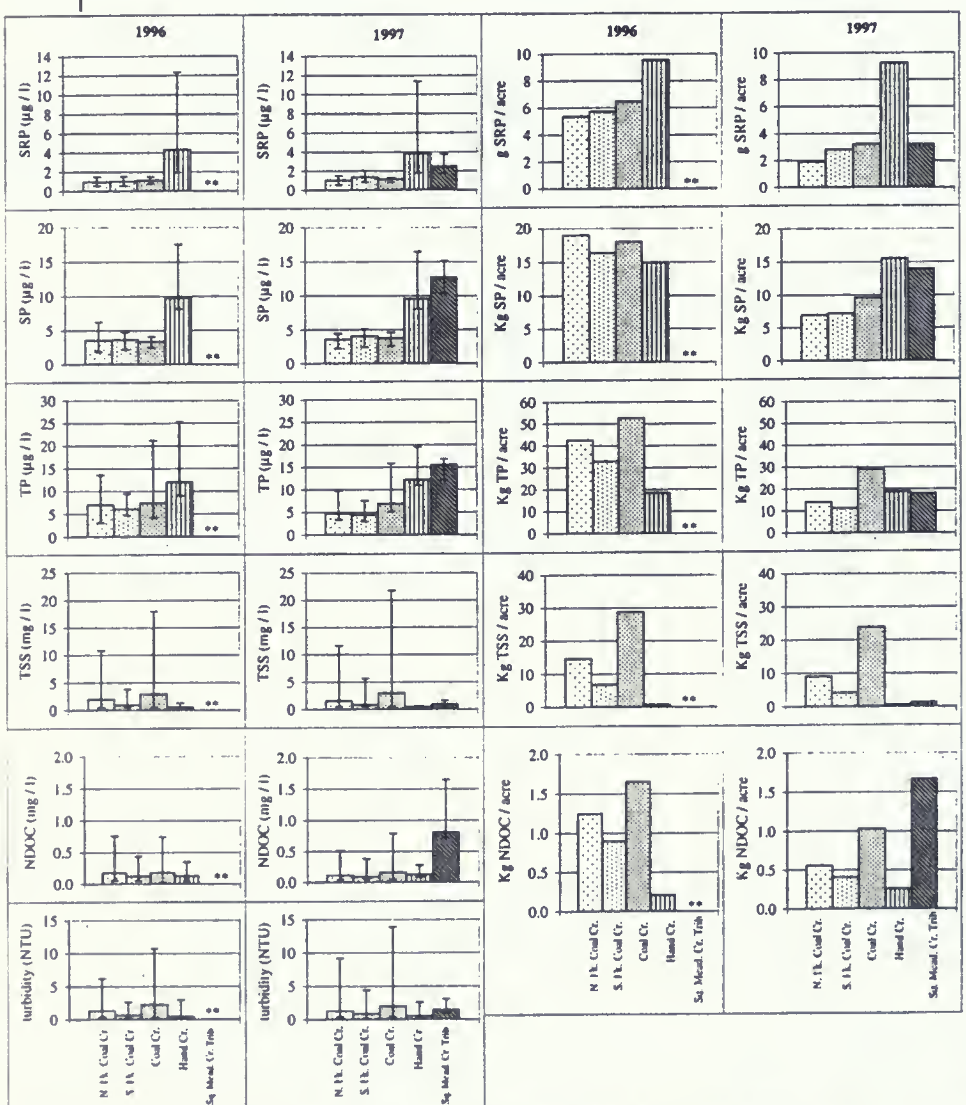


Figure 5. Mean concentration of soluble reactive phosphorus (SRP), soluble phosphorus (SP), total phosphorus (TP), total suspended solids (TSS), non-dissolved organic carbon (NDOC) and turbidity for the 1996 and 1997 project periods (left series). Bars depict range of values for each period. Total load per acre of the catchment (right series) is also given.
** Site not sampled in 1996

Yearly precipitation at the Upper Hand Creek site ranges from 25 to 28 inches while the Coal Creek catchment receives about 30 to 90 inches. Although the water yield per acre was much lower (i.e., ~1/5[th]) for Upper Hand Creek than the Coal Creek sites in 1996, loading of SRP per area in Upper Hand Creek was much higher and $NO_{2/3}$-N and SP loading were similar (Figures 4 and 5). In 1997, SRP loading per acre in Upper Hand Creek was 3X the loading from all other sites while the water yield per acre was lower than or similar to the other sites. Loads per acre for several other nutrients were relatively high considering the differences in water yield per acre (i.e., $NO_{2/3}$-N, TPN, SiO_2, SP and TP). The low TSS loads in Upper Hand Creek reflect the mild stream gradient and relatively low elevation headwaters.

During the early 1980's,

Upper Hand Creek was selected as a control monitoring site for comparison to other sites where forest harvest activities would take place. Unfortunately, by 1985, harvest began in the small Upper Hand Creek catchment. Almost 80% of the catchment has been harvested while the entire Hand Creek catchment has experienced timber harvest over nearly 60% of its area. This was partly the result of salvage logging after the Little Wolf Fire that occurred in late summer 1994; however, this catchment was heavily harvested prior to the fire. One study suggested that the elevated nitrate load at the upper site in 1995 might have been due, in part, to increased export of nutrients following wildfire.

Nutrient, carbon and suspended solids concentrations have been monitored in Upper Hand Creek since 1994 (Figures 6 and 7). Although total phosphorus has been measured in Upper Hand Creek since 1982, sample collection was sporadic (see Figure 8). When data were included only from the runoff period each year, there was a highly significant increase in total phosphorus ($p = 0.010$) for the entire period of record (i.e., 1982-1997). Additional analysis of the data, where the period after the fire (1994 summer-1997) was excluded showed no significant trend in increasing TP prior to the fire, but few data were available late in the pre-fire record (i.e., 1982-1994 summer). An examination of the nutrient, carbon and suspended sediment concentrations in Upper Hand Creek for the 1994-1997 period (Figures 6 and 7) indicated no highly significant increasing or decreasing trends in any variable. It is worth noting, however, that the regression of SRP over time showed an increasing trend that was significant at $p < 0.10$.

Spencer and Hauer (1998) studied the effects of the Red Bench Fire on nutrient export in streams of the Flathead National Forest and Glacier National Park over a long time period. They found that soluble reactive phosphorus concentrations were significantly higher for 3 to 5 years after the fire in relation to higher water yield. Hence, it is quite likely that wildfire contributed to the increased phosphorus observed in Upper Hand

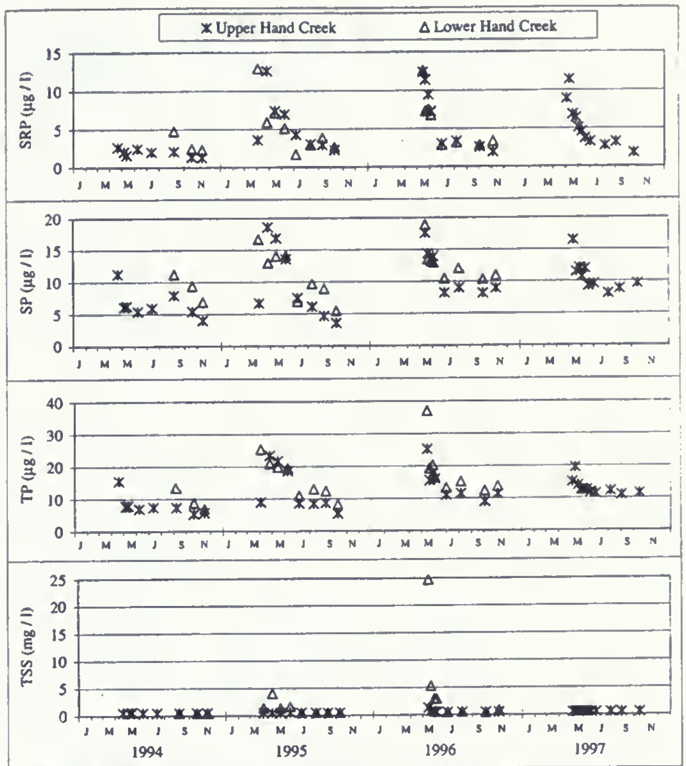


Figure 6. Concentration of soluble reactive phosphorus (SRP), soluble phosphorus (SP), total phosphorus (TP) and total suspended solids (TSS) from 1994 to 1997 for the Upper (asterisk) and Lower (triangle) Hand Creek sites.

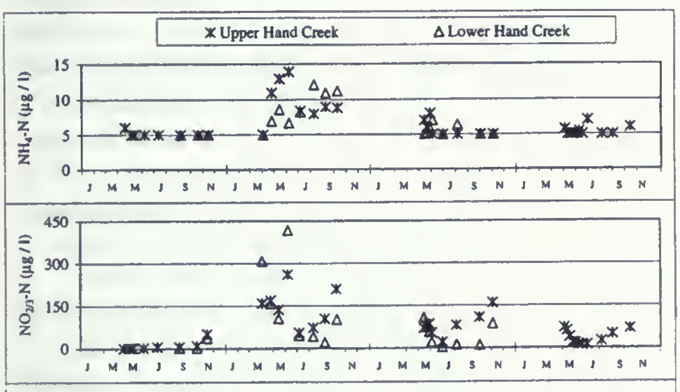


Figure 7. Concentration of amonium nitrogen (NH_4-N), nitrite plus nitrate nitrogen ($NO_{2/3}$-N), total persulfate nitrogen (TPN) and non-dissolved organic carbon (NDOC) from 1994 to 1997 for the Upper (asterisk) and Lower (triangle) Hand Creek sites.

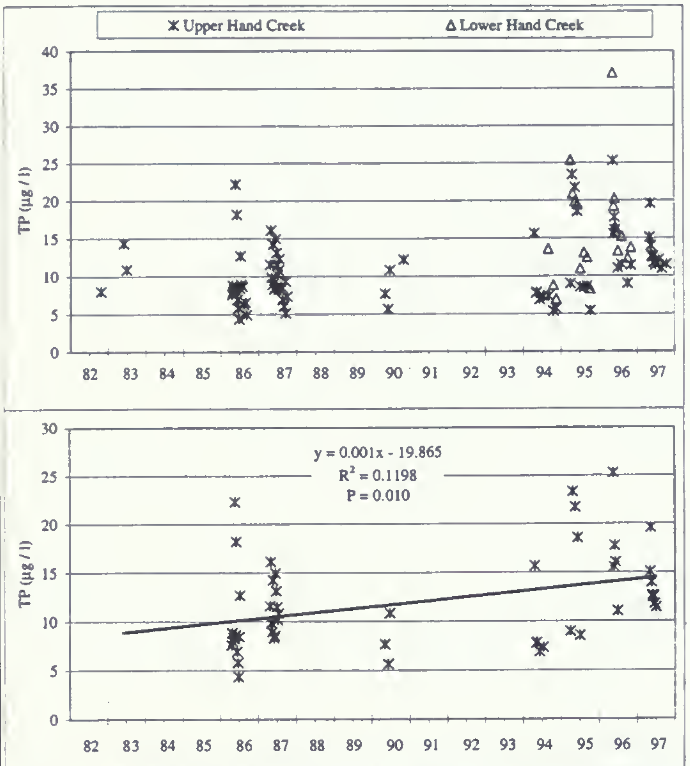


Figure 8. Total phosphorus (TP) concentrations from 1982 - 1997 for the Upper (asterisk) and Lower (triangle) Hand Creek sites. Also given is the linear regression for Upper Hand Creek data during spring runoff (April through July) from 1983 - 1997.

Creek. It is also possible that water yield or regime changes associated with management and fire may have also played a role.

Tributary to Squaw Meadow Creek Watershed

Water quality and discharge at this site have been monitored by the USFS since 1982, but sampling was often concentrated during the runoff period. In 1997, water quality was examined over several seasons. Seasonal patterns in SiO_2, TPN, TP, SP, TSS and turbidity were similar to those observed in Hand Creek (Figures 3a, b, c) with a few minor exceptions. SRP remained fairly low throughout the sampling period, with highest concentrations found during runoff and base flow. Two peaks in NH_4-N occurred during runoff and early summer, but values were generally near detection limit. The most striking differences occurred in the temporal patterns of NDOC and $NO_{2/3}$-N. This tributary carried relatively high particulate carbon during runoff in comparison to the other monitoring streams. Transport of particulate carbon from the terrestrial environment to the stream during snowmelt may have been greater and/or scouring of communities on bed sediments in the stream may have resulted in higher in-stream NDOC. The presence of a wetland upstream of the Squaw Meadow Creek site could also be a source of particulate organic matter as could a predominance of deciduous vegetation in the catchment, but the potential contribution of NDOC from these sources has not been quantified.

It is also interesting to note that TSS remained quite low during runoff, but turbidity was measurable and remained elevated after runoff (Figure 3a). Turbidity in the tributary to Squaw Meadow Creek was higher than all other monitoring sites during base flow. The relatively high turbidity was likely related to the presence of wetland meadows in the catchment. The stream was always brown in color, which suggested that the refractory compounds (e.g., the yellow-brown peaty stain of lignins, tannic and humic acids) common in many wetlands, were transported to the stream. Unlike all the other sites, a major decline in $NO_{2/3}$-N concentrations was not observed during runoff, but values remained quite low, increasing only during base flow (Figure 3c). Again, groundwater contribution of higher $NO_{2/3}$-N during base flow and dilution of $NO_{2/3}$-N during runoff are possible explanations. Sampling earlier in the spring may reveal higher $NO_{2/3}$-N prior to peak discharge. It appeared that this stream was relatively high in phosphorus and low in inorganic nitrogen. Low inorganic nitrogen and high organic nitrogen values suggested that much of the inorganic nitrogen was utilized by biota.

The tributary to Squaw Meadow Creek had the highest mean concentration of TPN, silica (SiO_2), NDOC, TP and SP in comparison to all of the other headwater monitoring sites (Figures 4 and 5). Mean particulate carbon (NDOC) was higher than all other sites. Mean total nitrogen (TPN) in the tributary to Squaw Meadow Creek was almost 2X higher than Hand Creek and 4X higher than all Coal Creek sites. Most of the nitrogen in the tributary to Squaw Meadow Creek was organic, as concentrations of inorganic nitrogen (i.e., $NO_{2/3}$-N and NH_4-N) were low.

Yearly precipitation at the tributary to Squaw Meadow Creek site ranges from 25 to 28 inches while the Coal Creek catchment receives about 30 to 90 inches. Although the water yield per acre for the tributary to Squaw Meadow Creek was about half that of the Coal Creek sites, the load/acre of

TPN, SiO_2, SRP, SP, TP and NDOC was similar or much higher (Figures 4 and 5). The tributary to Squaw Meadow Creek transported more NDOC and organic nitrogen per catchment area during the 1997 project period than all of the other monitoring sites and SP loading/acre was also relatively high.

<u>Correlations Between Harvest Intensity and Water Quality</u>

All of the headwater sites monitored in 1997 had some level of harvest in their respective watersheds, so no comparisons could be made to unmanaged or wilderness sites. However, we found 3 significantly positive correlations between water quality, measured in terms of mean annual nutrient concentrations (N, P and C forms) and harvest intensity, measured as either road miles per acre or percent of watershed harvested: 1) total phosphorus and road miles per acre, $r^2 = 0.79$, $p = 0.117$, 2) NDOC and road miles per acre, $r^2 = 0.82$, $p = 0.092$, and 3) $NO_{2/3}$-N and percent harvest, $r^2 = 0.91$, $p = 0.076$ (see Figure 9). These regressions are conservative, because the Lower Coal Creek site was not included in the data set. This was due to the possibility of bias resulting from some interdependence between the North and South Forks and the Lower Coal site. The relatively solid statistical significance of these correlations is surprising given the few number of sites that were used (and, thus, the low degrees of freedom) in the statistical analysis. These results indicated that as the road miles per acre increased in the catchments, total phosphorus and particulate carbon concentrations in the monitored streams increased proportionately. The data also indicated that as the percent harvest increased, nitrate plus nitrite nitrogen concentration in these streams increased proportionately.

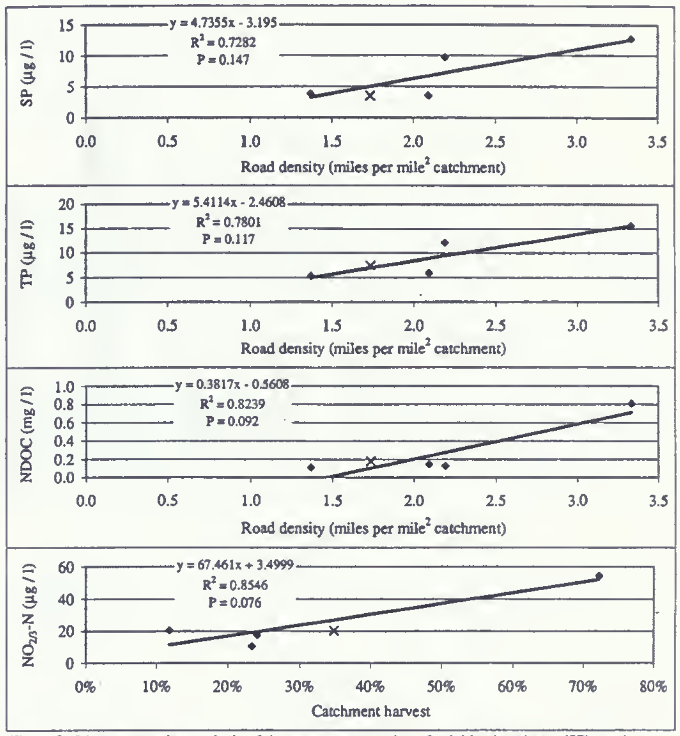


Figure 9. Linear regression analysis of the mean concentration of soluble phosphorus (SP), total phosphorus (TP) and noo-dissolved organic carbon (NDOC) in 1996 and 1997 as a function of road density (miles per catchment acre) and nitrite plus nitrate nitrogen ($NO_{2/3}$-N) as a function of catchment harvest, using the N. Fork Coal Creek, S. Fork Coal Creek, Hand Creek and the Tributary to Squaw Meadow Creek (black diamonds). Also present, but not used in the regression analysis, is the mean for Lower Coal Creek (black X).

Conclusions:

The statistically significant correlations between higher nutrient concentrations and harvest/road intensity in our time series analyses support the findings of Hauer and Hill (1997). Logging and road building in the Flathead Basin are generally associated with nutrient (N, P and C) losses from watersheds. Loading of nutrients to the tributaries of the Flathead River from harvested headwaters are consistently above the background of natural variation.

Much longer term data are needed to draw definitive conclusions in the highly variable landscapes of the upper reaches of the Flathead River Basin, given the likelihood of significant natural variation in soils, land cover, discharge and other watershed attributes that directly influence nutrient export from watersheds.

Controlled experimental designs, including, for example, pairs of headwater sub-basins of similar biophysiography, with and without harvest and roading of similar prescription, and long-term data are required to clearly and unambiguously quantify the effects of forest management on water quality in the Flathead Basin.

Headwater Streams in State Forests

The Montana Department of Natural Resources and Conservation, Trust Land Management Division, (formerly Department of State Lands) began monitoring water quality at selected sites on the Stillwater State Forest near Olney, Montana, in 1976 (Table 1). Sampling locations are in both the Whitefish Lake and Stillwater River basins. The objective of the monitoring program is to detect trends in discharge, nutrients, and sediments, to identify relationships between management activities and water quality, and to establish baseline values for comparison over time.

Chepat Creek and Chicken Creek are considered to be indicative of undisturbed watersheds due to the negligible amount of timber harvest and road building which has occurred in the basins. The primary land-owner within the Lazy Creek drainage is Plum Creek Timber Company. The station on this stream is monitored with their financial support.

STATION NAME	STATION CODE	PERIOD OF RECORD
East Fork Swift Creek	STSF01	1976-PRESENT
West Fork Swift Creek	STSF02	1976-PRESENT
Chicken Creek	STSF03	1976-PRESENT
Middle Swift Creek	STSF05	1981-PRESENT
Lower Swift Creek	STSF06	1976-PRESENT
Chepat Creek	STSF08	1976-PRESENT
Lower Fitzsimmons Creek	STSF09	1976-PRESENT
Lazy Creek	STSF10	1985-PRESENT
Upper Fitzsimmons Creek	STSF11	1995-PRESENT

Table 1. Period of Record for Water Quality Monitoring Stations on the Stillwater State Forest

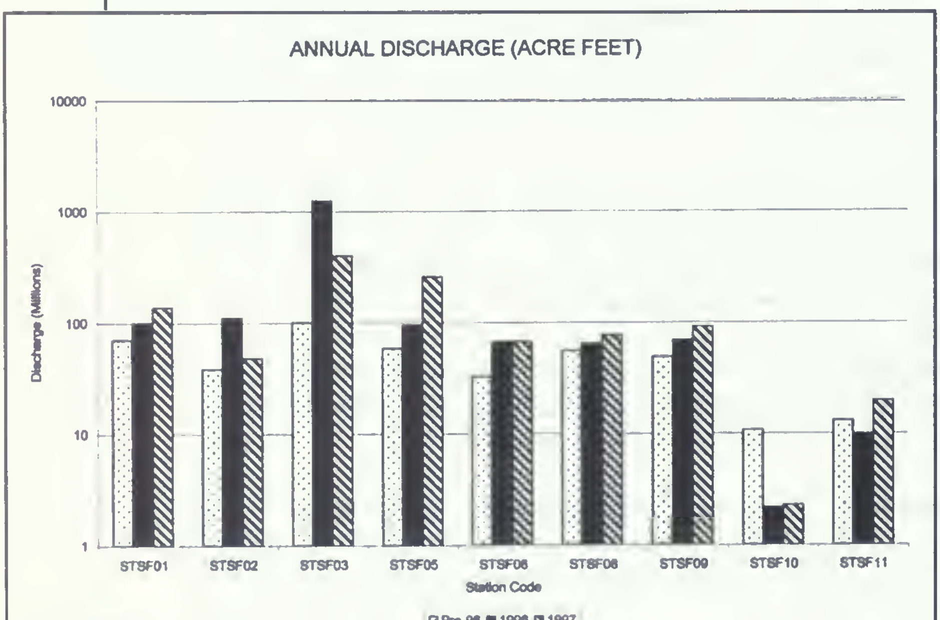


Figure 1.

Water Yield

Increases in water yield from a given drainage may result from either greater precipitation or a reduction in water usage by vegetation as a result of timber harvest or fire. Precipitation levels in the Flathead Valley were generally above normal in 1996 and below normal in 1997. This trend is reflected in the discharge figures depicted in Figure 1. With the exception of Lazy Creek and Upper Fitzsimmons , all locations showed water yield levels in 1996 and 1997 to be above the pre-1996 values. The increases in 1997 may be attributed to the timing and duration of runoff, rather than total precipitation.

Assuming that the drainages in the Stillwater have similar geology, water yield per unit area should be relatively constant for areas with similar snow accumulation and melt regimes. Water yield per acre figures are shown in Figure 2. The general trend shown is that the water yield in 1996 and 1997 was near or above the pre-1996 average. The fact that this trend is seen consistently at all stations including Chicken and Chepat Creeks, which are essentially unroaded and without timber harvest, is evidence that the cause of this water yield increase is natural. The lower elevation watersheds show a lower magnitude increase which indicates that the cause may be associated with increases in snowpack.

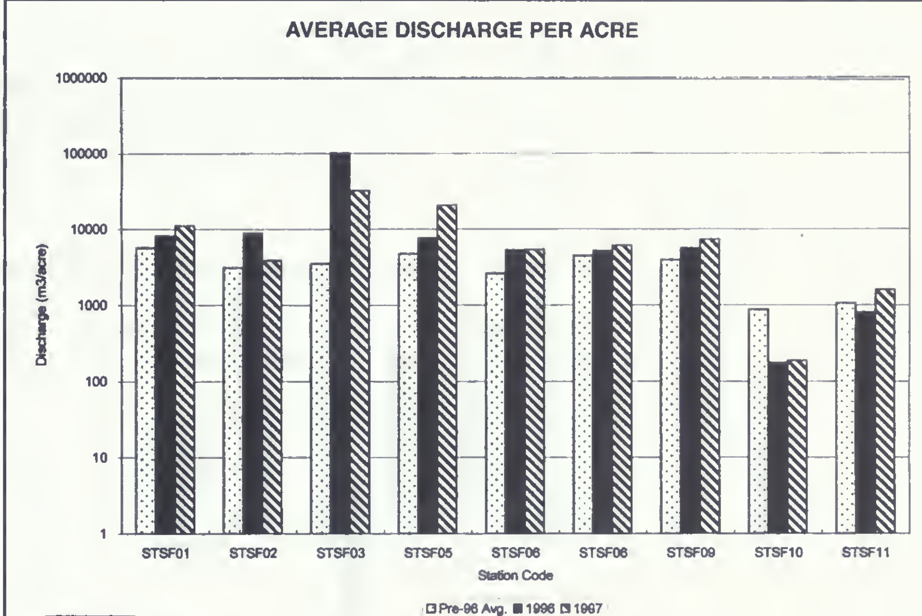


Figure 2.

Sediments

Streams naturally carry a certain sediment load. This load is determined to a large extent by the type of soil which the stream flows through, the nature and extent of the streamside vegetation, and the amount of flow in the stream. Changes in any of these factors will change the amount of sediment available to the stream. Hydrologists look for variation in suspended sediment concentration over time to indicate changes in water quality. Phosphorus has been shown to be associated with sediment so, by monitoring the sediment levels we may also be able to draw conclusions about the nutrient loading to downstream waterbodies. In addition to carrying nutrients, fine sediment, in large amounts, can have a detrimental effect have on the spawning cycle of fish.

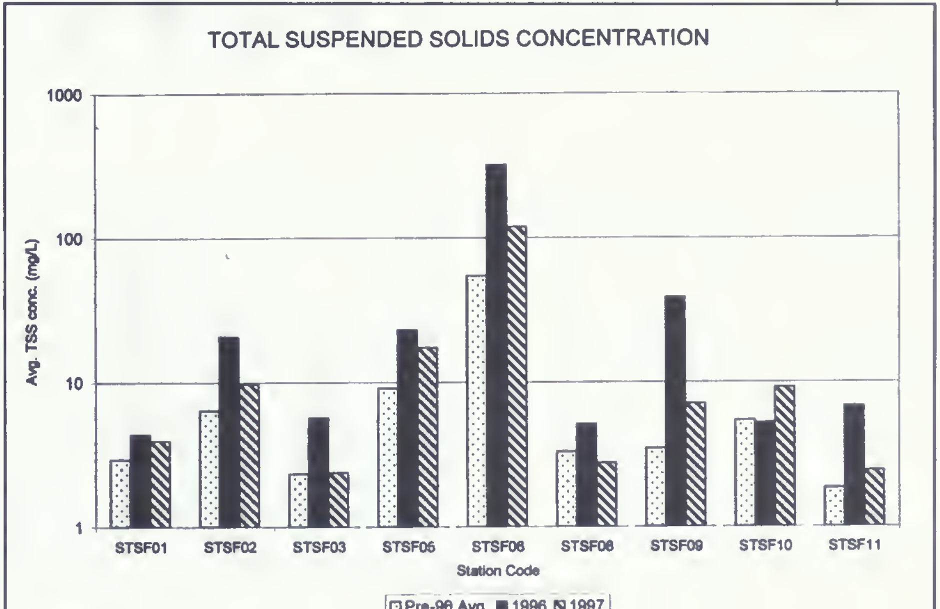


Figure 3.

Average sediment concentrations for each annual sample period are shown in Figure 3. With the exception of Lazy Creek , all sites in 1996 showed values above average. In 1997, all values except Chepat Creek were also above average. The large percentage increase seen at each station is difficult to explain. An analysis of covariance (ANCOVA) revealed highly significant differences between discharge and total suspended solids at all stations for the entire period of record. There has been no management activity in any of the drainages except

Swede Creek, which is above the Lower Swift Creek sampling site, within the last several years. The average sediment concentrations passing the Lower Swift Creek station (just above Whitefish Lake) in 1996 and 1997 were higher than the average concentration over the previous years of record. The exceptionally large sediment concentrations observed at the Lower Swift Creek station are a result of mass wasting banks which occur naturally in the lower reaches of Swift Creek.

Nutrients

Studies of Whitefish and Flathead Lakes have concluded that increases in nutrient concentrations will further stimulate algal productivity and should be minimized. The nutrients which are of concern in this system are phosphorus and nitrogen, these will be discussed in turn.

Phosphorus

It has been speculated that the primary sources of phosphate in the Stillwater River and Whitefish Lake drainages are decomposed organic matter and phosphorus compounds stored on sediments. Numerous previous studies have shown a high correlation between phosphorus concentrations and, both sediment concentration, and stream discharge.

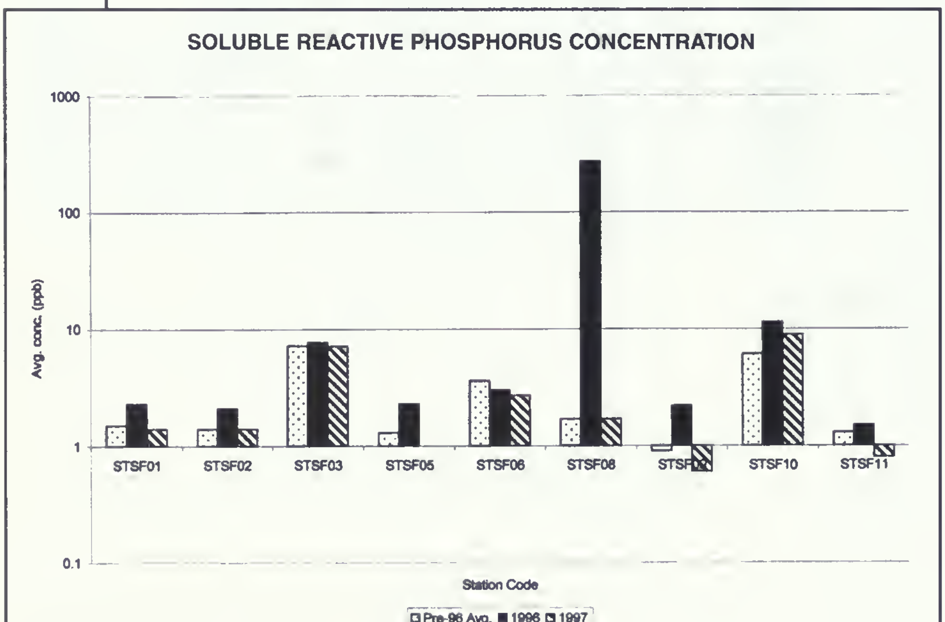


Figure 4.

One of the primary objectives of the water quality monitoring on the Stillwater State Forest is to attempt to understand the relationship between forest management activities and phosphorus concentrations being delivered to downstream waterbodies. To date this relationship continues to be poorly understood. Figure 4 shows the values for average soluble reactive phosphorus (SRP) concentrations. There appears, from this data, to be poor correlation between forest management and SRP concentrations. For example, Chicken Creek and Chepat Creek , which have had very little timber harvest and road building activity shows relatively high SRP concentrations. The values are higher, in fact than those for Lower Fitzsimmons where recent timber harvest and road construction have taken place.

The EPA recognizes that numerical water quality standards for phosphorus must be developed on a site specific basis. A standard which is often given as the acceptable concentration for surface water which deliver to a lake is 50 parts per billion (ppb) of total phosphorus. This concentration was exceeded on three sample dates in the 1996-1997 seasons. Figure 5 shows the values for average total phosphorus (TP) concentrations. All of the exceedance dates were in the spring and early summer,

during high flow. Throughout the period of record there have been numerous exceedances of the 50 ppb standard. These have occurred at all sampling locations, including the locations in effectively undisturbed basins. This fact indicates that the 50 ppb standard for total phosphorus may not be appropriate for streams in the Stillwater State Forest.

Nitrogen

Another nutrient which may contribute to problematic algal productivity is nitrogen, specifically, in the form of nitrate (NO_3). Figure 6 shows an unexpected pattern of nitrate concentration. There seems to be little correlation between nitrate concentrations and forest management activities or drainage area. With the exception of Chicken Creek, the watersheds in the Swift Creek drainage had nitrate concentrations greater that watersheds in the Stillwater River drainage by approximately an order of magnitude. This would seem to indicate that there is some natural source of higher concentrations of nitrate in Swift Creek or some inherent buffering capacity of the land in the Stillwater drainage. An analysis of variance for Discharge vs NO_3 also showed no significant differences for all the Stillwater stations, while the Swift Creek stations, with the exception of Chicken Creek, resulted in significant variance at the 95% confidence interval.

One sample in the spring of 1993 exceeded 0.30 parts per million level, which is recommended by the Department of Environmental Quality as a reasonable standard for nitrate. All other samples in every year have been below this level.

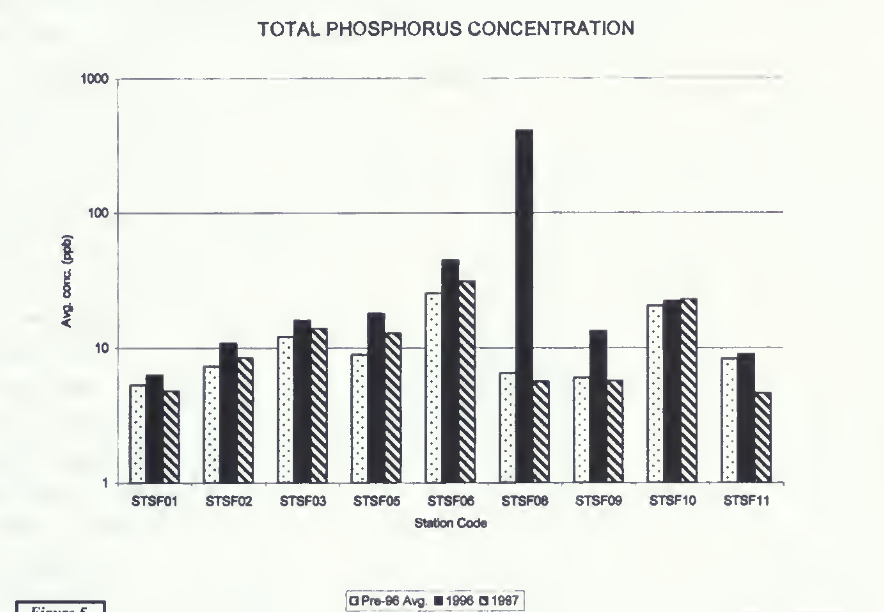


Figure 5.

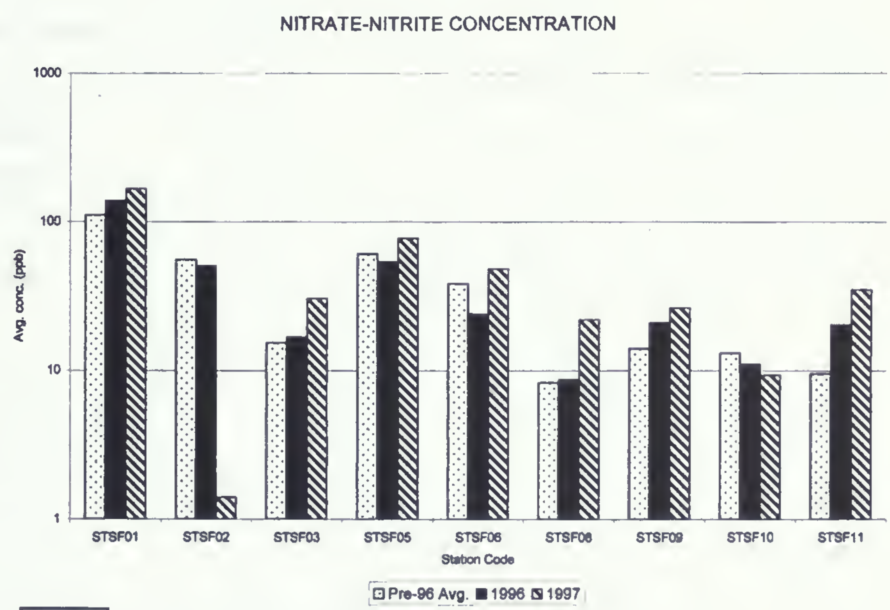


Figure 6.

Selected Lakes in Glacier National Park

In order to establish a water quality baseline for lakes in Glacier National Park (GNP), the National Park Service and the Flathead Lake Biological Station began a cooperative monitoring program in 1984. Data were collected every summer and fall through 1990, with the objective of documenting the annual variability in water chemistry, physical characteristics, and phytoplankton and zooplankton communities of selected park lakes. Five large frontcountry lakes, which are heavily used by park visitors and have lakeshore developments (e.g., hotels, cabins, commercial boating), were monitored along with eight backcountry lakes, which are located in very remote, alpine headwater areas of the park. A summary of the baseline monitoring was reported by Ellis et al. in 1992.

In November 1992 the Flathead Basin Commission (FBC) asked an interagency group to re-examine the goals and objectives of the Master Plan for Monitoring Water Quality in the Flathead Basin (FBC 1986). The interagency Technical Advisory Committee JAC) submitted their report to the Monitoring Committee in December 1992. One of the important recommendations of the TAC was that the long-term monitoring of upper basin lakes should be continued, particularly in lakes where important native fisheries exist or sites known to be sensitive to acid precipitation. Using the database summarized by Ellis et al. (1992), National Park Service personnel selected 3 backcountry lakes for continued long-term monitoring of water quality. Results of the 1997 monitoring of these lakes are presented here.

Table 1. Biophysical variables and methods used in monitoring water quality.

Variable (units)	Method (references)	Detection limit
phosphorus (μg/l-P)		
total	persulfate digestion; modified automated ascorbic acid (1)	0.7
soluble total	filtration; persulfate dig.: mod. auto. ascorbic acid(1)	0.7
soluble reactive	filt.; mod. auto. ascorbic acid (1)	0.3
nitrogen (μg/l-N)		
total persulfate	persulfate digestion (2); auto. cadmium reduction (1)	20
nitrite + nitrate	auto. cadmium reduction (1)	0.6
ammonia	auto. phenate (1)	5.0
dissolved silica (mg/l SiO_2)	auto. molybdate-reactive silica(1)	0.2
carbon (mg/l-C)		
non-dissolved organic	persulfate dig.; infrared CO_2 detection(3)	0.10
carbonate alkalinity (mg/l-$CaCO_3$)	titration (1)	0.5
turbidity (NTU)	nephelometry(1)	0.01
total suspended solids (mg/l)	gravimetric (1)	0.5

[1]APHA, 1985
[2]D'Elia *et al.*, 1977
[3]Menzel and Vaccaro, 1964

Table 2. Nutrient variables quantified in grab samples from lakes in Glacier National Park, 1997, in comparison to the mean ± 1 standard deviation for samples collected during the period 1984-1990 (Ellis et al. 1992).

Site	NH_3N (μg/l)	$NO_{2/3}N$* (μg/l)	TPN** (μg/l)	SRP (μg/l)	SP (μg/l)	TP (μg/l)
Cobalt Lake	5.0 6.1 ± 1.6	0.7 13.4 ± 13.7	73.0 79.9 ± 33.2	0.3 1.0 ± 0.2	1.9 1.4 ± 0.6	4.6 4.4 ± 1.0
Gyrfalcon Lake	5.0 7.6 ± 2.9	40.0 26.9 ± 25.1	82.0 72.4 ± 26.1	0.5 1.0 ± 0.2	1.1 1.8 ± 1.0	3.9 3.4 ± 0.8
Upper Dutch Lake	5.0 6.7 ± 1.6	0.7 19.8 ± 27.5	64.1 101.1 ± 59.0	0.3 1.1 ± 0.2	1.8 2.0 ± 0.9	4.5 6.8 ± 1.8

*Prior to 1988, nitrite and nitrate nitrogen were determined separately. $NO_{2/3}N$ was calculated by adding nitrate to the nitrite concentration.
**Prior to 1987, total nitrogen was determined by adding the $NO_{2/3}N$ concentration to the total keldahl nitrogen (TKN) concentration.

Methods

The Flathead Lake Biological Station worked cooperatively with Glacier National Park in 1997 in the examination of baseline water quality in Gyrfalcon Lake , Upper Dutch Lake , and Cobalt Lake. National Park Service personnel collected grab samples from approximately 0.5 m depth near the shoreline of each of the three lakes during the ice-free period and transported them to the Flathead Lake Biological Station for analysis.

Chemical analyses on water collected from the lakes listed above included: total

suspended solids (TSS), nitrate plus nitrite nitrogen , ammonia , total nitrogen , soluble reactive phosphorus, soluble total phosphorus , total phosphorus , dissolved silica , turbidity , non-dissolved organic carbon and alkalinity (Table 1). A filter blank was prepared for quality control purposes.

Table 3. Chemical variables quantified in grab samples from lakes in Glacier National Park, 1997, in comparison to the mean ± 1 standard deviation for samples collected during the period 1984-1990 (Ellis et al. 1992).

Site	ALK (mg/l)	SiO_2 (mg/l)	NDOC (mg/l)	TSS (mg/l)	TURB (NTU)
Cobalt Lake	5.9 5.0 ± 1.3	0.8 1.2 ± 0.5	0.15 0.28 ± 0.06	0.76	0.27 0.40 ± 0.12
Gyrfalcon Lake	15.7 16.3 ± 4.5	0.6 0.7 ± 0.2	0.09 0.17 ± 0.14	0.50	0.38 0.31 ± 0.07
Upper Dutch Lake	12.3 9.8 ± 3.8	1.9 1.8 ± 0.4	0.16 0.43 ± 0.24	0.54	0.39 0.45 ± 0.37

Results

Nutrient concentrations for Cobalt, Gyrfalcon and Upper Dutch Lakes were similar to concentrations observed during the 1984-1990 baseline monitoring (Table 2, Figure 1). The concentration of soluble reactive phosphorus in Upper Dutch Lake appeared to be somewhat lower than previous values. However, detection limits have improved from 0.8 µg/l during the mid-1980s to 0.3 µg/l at present. Previous values that were below detection limit (i.e., <0.8 µg/l) were included in the average as 0.8 µg/l, thus potentially raising the mean for 1984-1990 above the true concentration. All other chemical variables were within previously reported ranges, except non-dissolved organic carbon in Cobalt and Upper Dutch Lakes (Table 3, Figure 1), where values were slightly lower than those measured from 1984 to 1990.

These lakes have extremely good water quality. Analysis of samples obtained in 1997 indicated that these lakes have not changed significantly since the baseline monitoring effort of 1984- 1990. Continuous monitoring should provide a means for detecting any major changes in trophic status.

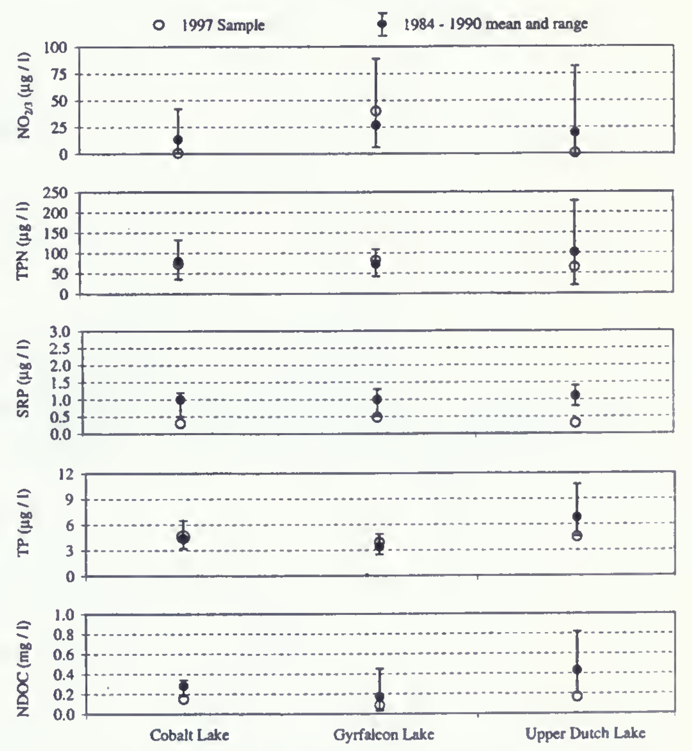


Figure 1. Comparison of 1997 carbon, nitrogen and phosphorus concentrations in grab samples from Cobalt, Gyrfalcon and Upper Dutch lakes in Glacier National Park to the 1984 - 1990 mean and range (Ellis et al. 1992).

It is recommended that the analysis of TSS be discontinued (a long-term record for turbidity exists) and that pH be added to the variable list. These lakes have such poor buffering capacity that acid precipitation could have an effect on the hydrogen ion concentration (pH). In addition, a more frequent documentation of water chemistry, physical characteristics, and phytoplankton and zooplankton communities should be completed on each of the lakes that were monitored during 1984-1990 in order to assess possible changes in water quality.

Fisheries

Fisheries in the Flathead Basin continue to be a major component of the Master monitoring Plan. The Flathead is one of a very few areas in the country still supporting self-sustaining populations of native westslope cutthroat and bull trout. These species are particularly sensitive to environmental disturbance and are used as indicators of aquatic habitat quality. The USFWS listed bull trout as a threatened species under the Endangered Species Act in June of 1998. They are currently conducting a one-year status review for westslope cutthroat trout, to be followed by a listing decision in 1999.

Flathead Basin monitoring has shown changes in habitat quality and declines in bull trout abundance in parts of the basin during the period of record. This monitoring includes counting the number of redds (individual spawning sites) and tracking juvenile fish abundance, as well as indexing both spawning and rearing habitat quality at specific sites basin-wide. Information from these monitoring activities is being used by both the state and USFWS to evaluate regulations and formulate recommendations for management and recover actions.

Bull Trout

Bull trout are a glacial relict species. They have extremely strict habitat requirements. The fact that they are still present here illustrates that water quality is good and suitable habitat is present. Because bull trout are good indicators of aquatic ecosystem health, the Flathead Basin Commission's Master Monitoring Plan calls for a program to track bull trout population and habitat status basin-wide. This ongoing program now provides one of the most extensive bull trout data sets available.

Historically, Flathead Basin bull trout had access to all three forks of the Flathead River, as well as other interconnected streams and rivers upstream and downstream of Flathead Lake. The downstream extent of this range was likely Albeni Falls, below Lake Pend Oreille. Although bull trout had access to all this area, their preference for colder water temperatures likely restricted their distribution and movement. For example, in larger lakes with surface outflow, summer/fall temperatures downstream are higher than migrating bull trout spawners prefer. Adult fish do not move through this warmer water, so the populations occupying these lakes remain separated. Migration of spawning bull trout from Flathead lake up into the Swan River's warmer water below Swan Lake was unlikely even prior to Big Fork Dam. Similar conditions occur below Flathead Lake, Stillwater Lake, Whitefish Lake, Big Salmon Lake and many of the lakes in Glacier National Park. Recent genetic testing has shown the bull trout in Big Salmon, Swan River and Stillwater River tributaries are indeed genetically distinct from each other as well as from those in Flathead River tributaries. It is likely that fish in Whitefish, Upper Whitefish, Cyclone, Frozen and each of the Glacier Park lakes are also genetically distinct, although little testing has been completed to date.

There are presently three major bull trout populations occupying the Flathead Basin: Flathead Lake and the North and Middle Forks of the Flathead River; Hungry Horse Reservoir and the South Fork of the Flathead River; and Swan Lake and the Swan River upstream from the lake. All three of these populations are dominated by a migratory life history. The adult fish reside in the lakes, but travel upstream to tributary streams where they spawn. After hatching, juvenile fish grow from one to four years in natal streams before migrating downstream to lakes where they mature at about age six.

Flathead Lake Population

During the past 20 years, Montana Fish, Wildlife and Parks (FWP) had monitored known spawning areas in four tributaries to each of the North and Middle Forks of the Flathead River (Figure 1). Fish spawning in these streams spend their adult lives in Flathead Lake. These eight index areas account for approximately 45 percent of the total annual spawning run from Flathead Lake.

Our initial year of redd counts (1979) is not directly comparable , but from 1980 on, the sections and methods have been identical. During the 12-year period from 1980 through 1991, the Flathead

Lake index count averaged 372 redds, ranging from a low of 243 in 1991 to a high of 600 in 1982 (Figure 1). A large decline in bull trout redd numbers occurred in the early 1990s. Various indices, several of which are part of the Commission's Master Monitoring Plan, show this change resulted from a declining trend in spawning and rearing habitat quality, followed by a major alteration in the trophic dynamics in Flathead Lake after establishment of *Mysis relicta.* Department personnel first detected *Mysis* in Flathead Lake in 1981. *Mysis* densities increased exponentially, peaking in 1986. It appears that the presence of *Mysis* enhanced Lake Superior whitefish and lake trout survival and growth. The fish community composition and species abundance has shifted dramatically from dominance by native species and kokanee salmon to dominance by these two introduced fish species.

From 1992 through 1997 the Flathead Lake index count remained low, but relatively stable. Counts averaged 120 redds during this six year period with a low of 83 in 1996 (Figure 1). This represents a reduction of approximately 70 percent from the 12-year period between 1980 and 1991. The 1998 index count of 187 redds is the highest since 1991 (Figure 1). This increase in spawner escapement is a definite improvement, especially in light of the improving trend in spawning and rearing habitat quality and higher juvenile abundance observed during 1998 surveys.

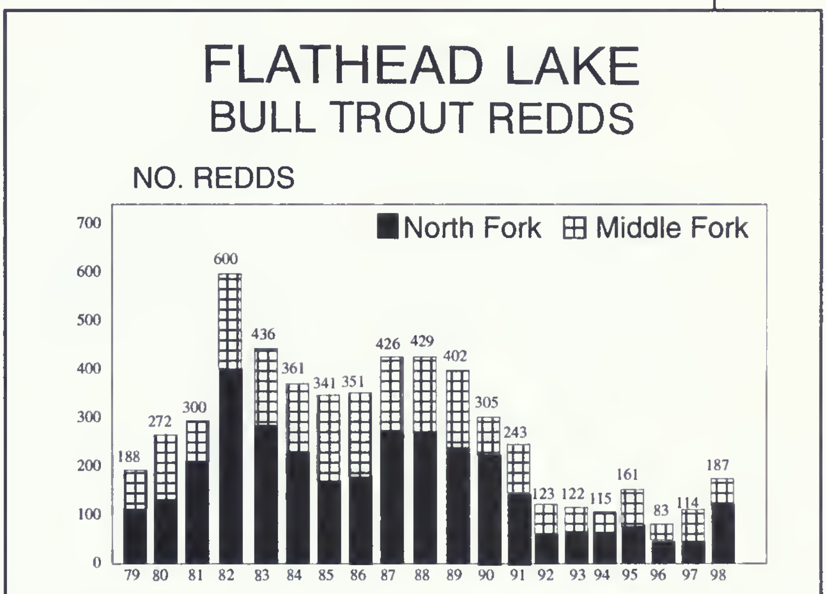


Figure 1

There are several possible explanations for the higher counts during our 1998 surveys. It is likely that a combination of factors resulted in the improved counts. First, increased spawner escapement during 1998 may represent a single strong yearclass resulting from any number of reasons, including improving tributary habitat. The higher counts may simply indicate better survival conditions for the 1998 cohort of spawning bull trout. A second possibility is that the progression of more restrictive angling regulations, coupled with intensified enforcement and angler education efforts over the past several years, are beginning to yield measurable results. It is equally possible that the trophic dynamics in Flathead Lake may be beginning to stabilize, and the level of negative interactions on bull trout is now less than it has been during the six previous years. Again, it is likely some combination of these factors has resulted in the higher counts during 1998.

Monitoring of spawning and rearing habitat quality has been part of the Commission's Master Monitoring Plan since the early 1980s. The Flathead Basin Cooperative Forest Practice Study is an excellent example of how the Commission assists in blending research and management to provide better protection of our aquatic resources. Streambed sampling techniques developed during this study have shown that the percentage of fine sediments increased throughout the drought period during the 1980s. Increases in fine sediments reduce the potential for survival in bull trout eggs and fry. The highest accumulation of fine sediments occurred in 1988, 89 and 90, but flushing flows since 1991 have improved conditions for both spawning and rearing. Currently, our monitoring shows tributary habitat quality is generally in as good or better condition than at any time since we began this program. Identification and remediation of existing sediment sources and water yield problems, along with application of Best Management Practices during recent or planned development activities should facilitate this positive trend. It appears that habitat conditions during the worst years (1988-90) may have been a limiting factor to the Flathead Lake bull trout population.

Juvenile bull trout abundance in Flathead tributaries has also declined during recent years, reaching an overall low in 1997. During the early 1990s we began to see weak year classes. Biologists believe tributary habitat capacity was reduced during the years when we documented the highest sediment levels. This decline in spawning and rearing habitat quality translated to a decreased number of juvenile bull trout during our 1990 surveys. Juvenile abundance recovered slightly in 1991 and 1992, but then changes in the ecological balance in Flathead Lake began to impact this population. From 1992 through 1997 there were several years when it was questionable whether nursery habitat which was undergoing an improving trend, was being adequately seeded due to low levels of spawning. These changes occurred after establishment of *Mysis* shrimp, which enhanced survival and growth of Lake trout and Lake Superior whitefish. Numbers of these two species peaked in 1989 and 1990, corresponding with the low redd counts observed between 1992 and 1997.

We observed a substantial increase in juvenile bull trout abundance during our 1998 surveys. When these higher juvenile densities are considered, along with the positive trend in tributary habitat quality and the higher number of bull trout redds observed during 1998, an encouraging trend is evident in the Flathead Lake bull trout population.

Swan Lake Population

During the past 17 years, FWP has monitored four trout spawning areas in tributaries to the Swan River (Figure 2). This work has been expanded during recent years and is presently a cooperative effort between FWP, Montana Department of Natural Resources and Conservation and Plum Creek Timber. Fish spawning in Swan River tributaries spend their adult lives in Swan Lake. This population appears to be increasing over our period of record (Figure 2). The four annual index areas contain approximately 70 percent of all bull trout spawning in the Swan River Drainage.

Biologists believe the increasing trend is due to an increased food supply for juvenile and sub-adult bull trout in Swan Lake resulting from establishment of *Mysis* shrimp. *Mysis* appear to be enhancing survival and growth of young bull trout in the absence of lake trout and lake whitefish. A second factor contributing to the observed trend may be more restrictive angling regulations and increased enforcement/education efforts during recent years. Currently, the entire river and tributary network is closed to fishing for bull trout. Swan Lake is the only water in the state where bull trout harvest is still allowed with a daily limit of one fish.

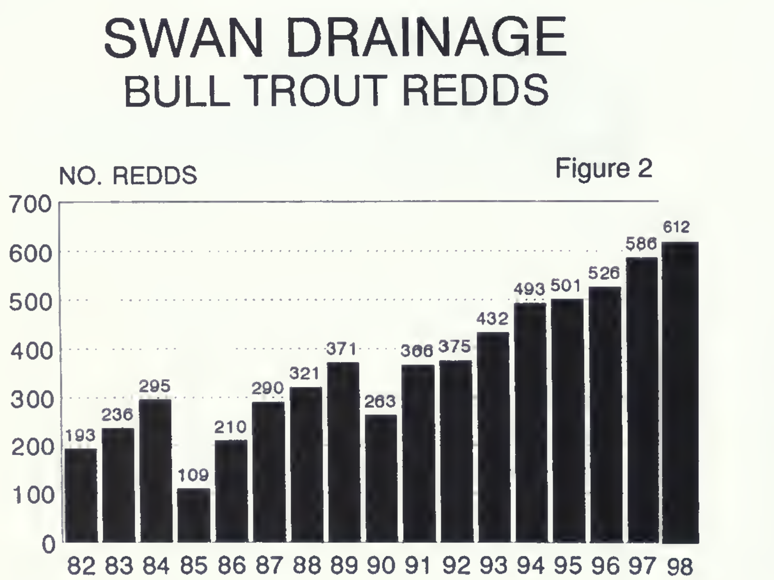


Figure 2

Spawning and rearing habitat quality are also monitored by FWP in cooperation with DNRC. Currently, conditions are good. Over our period of record, habitat quality in the Swan Drainage has shown a pattern of change similar to what was described for Flathead Lake tributaries. The effects of the drought years during the late 1880s are evident, but good water years since 1991 have improved sediment levels in critical spawning and rearing areas.

Juvenile bull trout abundance estimates show healthy populations in Swan Drainage index streams. Although this population appears stable or increasing at present, serious threats still exist. The greatest risk is from an illegal introduction of lake trout which are present in high numbers immediately downstream from Bigfork Dam. An angler caught a lake trout while fishing the Swan River

upstream from Swan Lake in 1998. It is not known how long this fish was in the Swan Drainage where it came from or if more are present. If lake trout become established, a scenario similar to what has occurred in Flathead Lake can be expected.

South Fork/Hungry Horse Reservoir Population

Bull trout redd numbers in tributaries to the South Fork of the Flathead River upstream from Hungry Horse Dame have held steady for the past six years (Figure 3). The 1998 count of 74 redds in the four index streams draining into the reservoir is slightly higher than the average of 66 during our period of record. The 1998 counts do not include the four backcountry index streams which were not surveyed due to time and funding constraints.

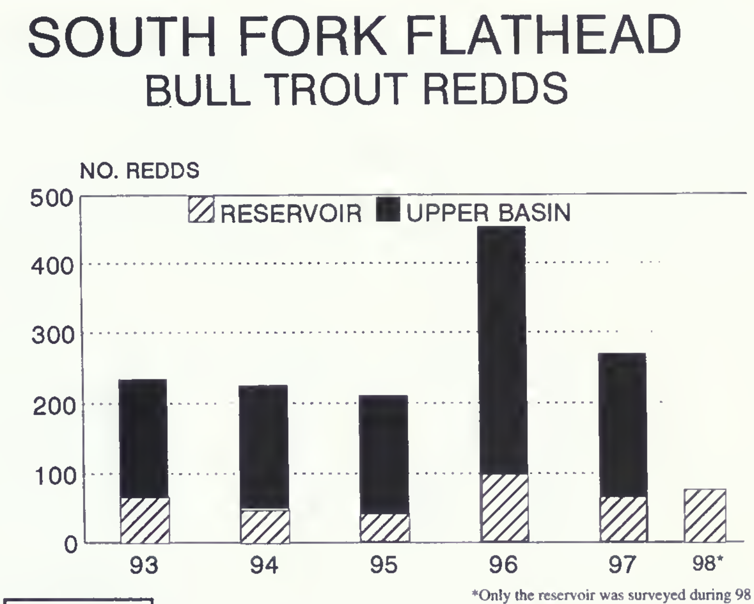


Figure 3

Redd counts were conducted in South Fork tributaries for the first time during 1993, so long-term comparisons are not possible. However, trend data from gillnetting in the reservoir since 1958 show relative stability in catch per net over this period. Because Hungry Horse Reservoir and the river upstream supports a native species assemblage and is largely not threatened by introduced species, it has become a critical refuge for westslope cutthroat and bull trout.

Hungry Horse Reservoir has been subject to extreme water level fluctuations such as the record 188-foot drawdown in April 1993. There are major concerns about the impact of deep drawdowns on native trout populations. Deep drawdowns occurred with regularity up through the mid 1990s due to drought, changing operations, power demands, and the need for water downstream to provide flow augmentation in the Lower Columbia River for ESA listed salmon recovery. Only the spawning runs from 1996 on have not been subjected to deep drawdown while in the reservoir. Recent angling restrictions may also have contributed to higher counts in recent years.

Major portions of the bull trout spawning and rearing habitat in the South Fork are protected by Wilderness designation. Habitat quality is presently in good condition. Our monitoring shows a similar pattern to what has been described for the Flathead lake and Swan Drainage tributaries, however our period of record is much shorter. A basin-wide redd count is proposed for 1999, after which areas selected for long-term indexing should be refined.

Disjunct Populations

There are 35 smaller lake populations of bull trout in Montana; 27 of these are in the Flathead Basin. Due to the overall lack of information regarding these bull trout populations, FWP began tracking several of these smaller, isolated populations. These data sets are not long enough to assess trends, but they do provide some indication of relative abundance. Monitoring occurs on the following lake systems: Whitefish, Upper Whitefish, Upper Stillwater, Cyclone, Frozen, Tally, Big Salmon, Holland and Lindbergh. There are 17 additional lakes in the Flathead Basin supporting bull trout where little information is available. The majority of these are located in Glacier national Park. Data on life history, population status and genetic structure should be a major focus of future Commission efforts.

Forestry Practices Update

Best Management Practices (BMPs) are voluntary guidelines that establish minimum accepted standards for timber harvesting, road building, and other timber management activities. The objective of BMPs is to protect water quality.

Since their formalization through legislative action in 1989, BMPs have helped those involved in timber management improve the application and effectiveness of their management practices.

Periodic audits are used to evaluate whether BMPs are being properly applied and if they are proving to be effective at limiting nonpoint source pollution on managed timberlands. Interdisciplinary teams used to conduct field audits include a fisheries biologist, forester, hydrologist, conservation group representative, road engineer, soil scientist, and a non-industrial private landowner or logging professional.

Summary of BMP and SMZ Application and Effectiveness, by Ownership Group

PRACTICE	DNRC	Federal	Industrial	NIP
BMP APPLICATION	96%	92%	95%	94%
BMP EFFECTIVENESS	99%	95%	95%	96%
SMZ APPLICATION	96%	96%	98%	94%
SMZ EFFECTIVENESS	100%	98%	100%	100%

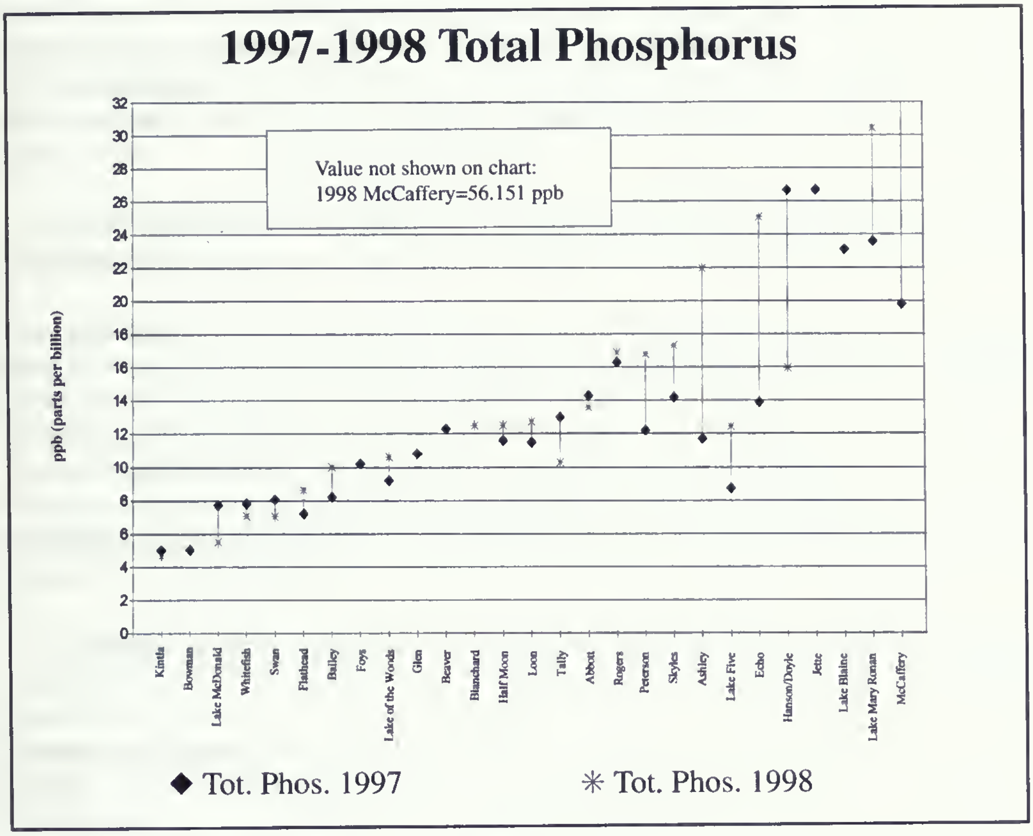
Results of the 1998 BMP audits reflect a continued improvement in scores for the four ownership groups — MDNRC, Federal, Industrial and Non-Industrial Private — for the application and effectiveness of both BMPs and the Streamside Management Zone (SMZ) Law.

For the first time, in response to a request from the Governor's Bull Trout Restoration Team, audits were conducted on 11 sites previously audited in 1994 or 1996, to assess whether BMPs are effective over time in minimizing erosion and the delivery of fine sediments to fish-bearing streams, and to determine which BMPs require modification to effectively control fine sediments.

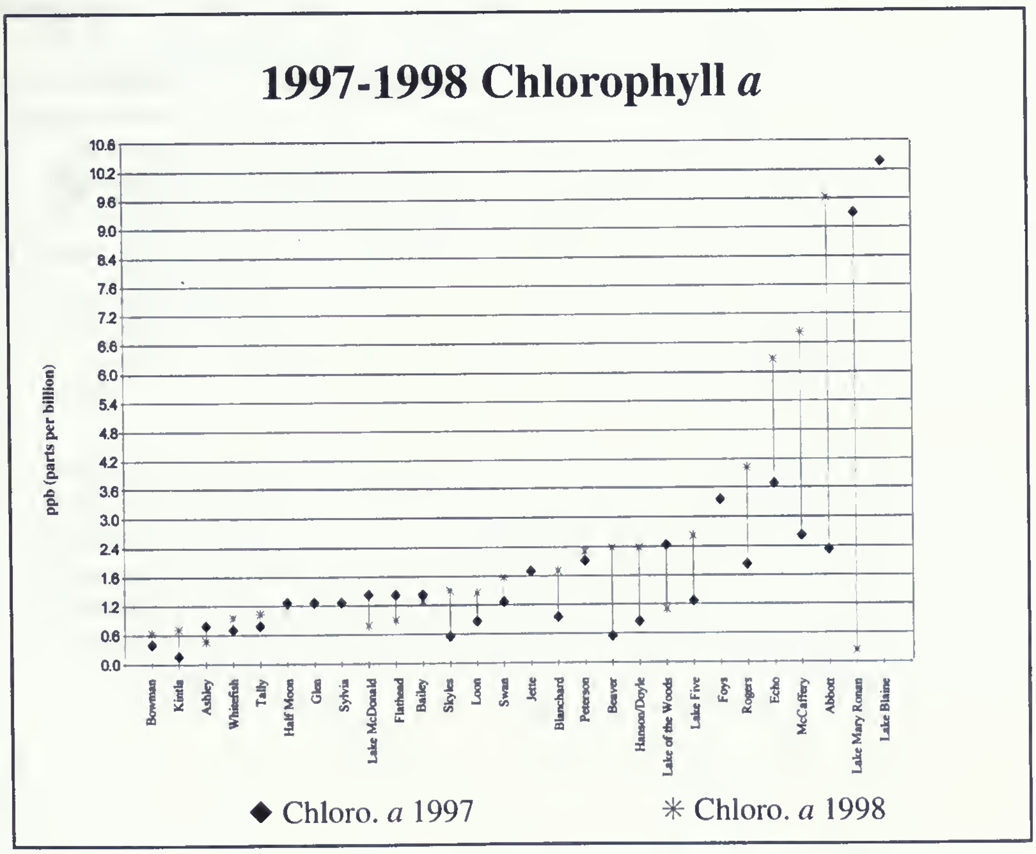
Comparison of BMP Audit Results - 1998 vs. 1996, 1994, 1992 and 1990

	1998	1996	1994	1992	1990
Application of practices that meet or exceed BMP requirements.	94%	92%	91%	87%	78%
Application of high risk practices that meet or exceed BMP requirements.	84%	81%	79%	72%	53%
Number of sites with at least one major departure in BMP application.	8 of 47 (17%)	12 of 44 (27%)	17 of 46 (37%)	20 of 46 (43%)	27 of 44 (61%)
Average number of departures in BMP application, per site.	2.0	3.0	3.9	5.6	9
Number of practices providing adequate protection.	96%	94%	93%	90%	80%
Number of high risk practices providing adequate protection.	89%	86%	83%	77%	58%
Number of sites having at least one major/temporary or minor/prolonged impact.	12 of 47 (26%)	15 of 44 (34%)	13 of 46 (28%)	17 of 46 (37%)	28 of 44 (64%)
Average number of impacts per site.	1.5	2.3	3	4.6	8

Volunteer Monitor Program Data



Total Phosphorus is the sum of all forms of phosphorus. In excessive amounts in lakes and streams, phosphorus can lead to over fertile (eutrophic) conditions and algae blooms. The higher the reading, the more serious the water quality problem.



Chlorophyll a is the green molecule in plant cells that carries out photosynthesis. It is used as an indicator of plant and algae productivity and acts as an empirical link between nutrient concentrations and other biological phenomena in lakes. Higher values suggest deteriorating water quality.

Summary of Monitoring Findings

1. During the 1997 water year, abundant snow accumulation at low elevations resulted in flooding of many of the lowland tributaries, likely increasing the transport of materials and associated nutrients and carbon into streams and rivers. Stream water inundated farm fields, grazing lands, ranchette developments, and other semi-urban areas in close proximity to streams.

- The mean total nitrogen and nitrate + nitrite nitrogen concentrations for the Stillwater River at Conrad Drive in 1997-1998 was substantially higher than the long-term mean (1977-1992).
- The mean nitrate + nitrite concentration for the mainstem Flathead River at Holt was higher in 1997-1998 than for the 1977-1992 period.
- The maximum nitrate + nitrite concentration that was measured during the 1997-1998 period exceeded the long-term range (1977-1992) of values observed for the Stillwater River.
- Higher nitrate + nitrite concentrations in the Stillwater River and the mainstem Flathead River at Holt were mirrored at the mid late deep site and at the lake outlet site at Polson.
- Total nitrogen and nitrate + nitrite means for mid lake deep (0-30m) in 1997 were outside the range of 1987-1996 means.
- Total phosphorus in Stoner Creek remained quite high compared to other streams in the Flathead Basin.

2. Mean annual pelagic primary productivity in Flathead Lake for the 1997 water year was higher than estimates for the previous four years. The 1997 mean exceeded the TMDL interim target for primary productivity. Elevated levels of nitrogen at mid lake deep suggested that nitrogen loading to the lake was probably high in 1997. Experiments strongly support the conclusion that growth of algae in Flathead Lake is controlled by nitrogen and phosphorus supply. It is important to remember that under certain conditions, food web changes may also influence primary production by altering the density of organisms that cycle these nutrients within the lake. The annual survey of *Mysis* in 1997 revealed the highest density recorded since the major peaks in 1986 and 1987. Alterations in the lake food web will continue as *Mysis* densities fluctuate so dramatically. Experiments have shown that if nutrient levels in Flathead Lake increase, organisms such as *Mysis* will become more important in regulating primary production; but, at current levels, nitrogen and phosphorus appear to be more important in controlling the algal community in the lake.

3. The water column profile of oxygen at Ross Deep on 19 August, 1997 showed gradual depletion of oxygen with depth but minimum values were not as low as in previous years. Reduced dissolved oxygen levels in the bottom layers at the site is of significance because hypolimnetic oxygen reduction is an indication of cultural eutrophication, a phenomenon linked to enrichment from nutrient pollution. Ammonium concentrations of the integrated sample and the 90 m sample at the mid lake deep site were the highest measured to date. Mean ammonium at mid lake deep for the 1997 water year was slightly higher than the target recommended by the TMDL Technical Committee.

4. Anabaena flos-aquae was observed as a floating scum in the area of the FLBS dock on 31 July 1997 and a sample was obtained for density and biomass analysis. Surface algal scum was not observed at the mid lake deep site during the 1997 water year, but surface samples collected during the late summer have not been analyzed. The TMDL interim targets recommend no measurable blooms of Anabaena flos-aquae (or other pollution algae) at the mid lake deep site. A lack of sufficient funding did not permit study and analysis of the biomass of lake shore periphyton, another TMDL interim target value.

5. The 1998 audit of Forestry Best Management Practices and application of Montana Streamside Management Zone law showed a continuing trend of improvement in practices in all categories.

6. Limited monitoring of logging and road building in the Flathead Basin indicates such activities may be associated with nutrient (nitrogen and phosphorus) and, more recently, carbon losses from watersheds. Total phosphorus and particulate carbon concentrations in monitored watersheds increased proportionately with road miles per acre. Nitrate plus nitrite nitrogen concentrations increased proportionately with area harvested in these watersheds. Valid assessment of alternative forest harvest prescriptions or restoration protocols (e.g., road obliteration) requires long-term monitoring of water and nutrient dynamics in streams in an experimental design encompassing the range of management alternatives.

7. The Flathead Basin has historically supported one of the largest migratory bull trout assemblages in the world. Presently, bull trout populations in the Swan and South Fork drainages are healthy, although population segments have seriously declined in Flathead Lake and the North and Middle forks of the Flathead River. The 1998 bull trout redd counts in these segments are encouraging, although, for a variety of reasons, it is uncertain if populations can reach former numbers. Threats to bull trout include:

- In rivers, illegal introductions, forest management activities, illegal harvest, and, in the South Fork of the Flathead above Hungry Horse Dam, extreme water level manipulations in the reservoir.

- In Flathead Lake, the establishment of *Mysis* and proliferation of lake trout and lake whitefish play a key role, although the actual mechanisms are not presently understood.

Scientific Report Bibliography

The Water Quality Monitoring section of the Biennial Report is derived from reports produced by various ongoing research projects. Those reports, available from the Commission office, include:

"Monitoring Water Quality in Flathead Lake, Montana, 1998 Progress Report," Open File Report Number 149-98 (by Bonnie K. Ellis, James A. Craft and Jack A. Stanford, Flathead Lake Biological Station, The University of Montana, 311 Bio Station Lane, Polson, Montana 59860-9659)

"Water Quality in Headwater Streaks in the Flathead National Forest: 1998 Biennial Report," Open File Report Number 151-98 (by Bonnie K. Ellis, James A. Craft and Jack A. Stanford, Flathead Lake Biological Station, The University of Montana, 311 Bio Station Lane, Polson, Montana 59860-9659)

"Report on Water Quality of the Stillwater State Forest" (1998, by George Mathieus, MDNRC Forest Management Bureau, 2705 Spurgin Road, Missoula, Montana 59804-3199)

"Water Quality of Selected Lakes in Glacier National Park, Montana" (1998, by Bonnie K. Ellis, Flathead Lake Biological Station, The University of Montana, 311 Bio Station Lane, Polson, Montana 59860-9659)

"Biennial Report: Monitoring Fisheries Habitat and Fish Populations in the Flathead Basin" (1998, by Tom Weaver, MFWP, 490 North Meridian Road, Kalispell, Montana 59901)

"Water Quality Data and Analyses to Aid in the Development of Revised Water Quality Targets for Flathead Lake, Montana" (1997, by Jack A. Stanford, Bonnie K. Ellis, James A Craft and Geoffrey C. Poole, The University of Montana, 311 Bio Station Lane, Polson, Montana 59860-9659)

"1998 Forestry BMP Audit Report" (MDNRC Forestry Division, 2705 Spurgin Road, Missoula, Montana 59804-3199)

"Volunteer Monitor Program 1996-1997 Comprehensive Report" (Flathead Basin Commission, 33 2nd Street East, Kalispell, Montana 59901)

APPENDIX

Flathead Basin Commission Establishing Legislation

75-7-301. Short title. This part may be cited as the "Flathead Basin Commission Act of 1983".

History: En. Sec. 1, Ch. 424, L., 1983.

75-7-302. Purpose. The purpose of the Flathead Basin Commission is to protect the existing high quality of the Flathead Lake aquatic environment; the waters that flow into, out of, or are tributary to the lake; and the natural resources and environment of the Flathead basin.

History: En. Sec. 2, Ch. 424, L. 1983.

75-7-303. Definitions. As used in this part, the following definitions apply:

(1) "Aquatic resources" means all beneficial uses of water, including but not limited to water quality and water supply; recreational, scenic, and aesthetic values; and fish, wildlife and other organisms.

(2) "Commission" means the Flathead Basin Commission established in 2-15-213.

(3) "Flathead basin" means all land and water areas the water from which drains into Flathead Lake or its tributaries.

History: En. Sec. 3, Ch. 424, L. 1983.

75-7-304. Duties of the commission. Duties of the commission are:

(1) to monitor the existing condition of the natural resources in the basin and coordinate development of an annual monitoring plan. This plan must involve a cooperative strategy among all land and water management agencies within the Flathead basin and identify proposed and needed monitoring which emphasizes but is not limited to the aquatic resources of the Flathead basin.

(2) to encourage close cooperation and coordination between federal, state, provincial, tribal, and local resource managers for establishment of compatible resource development standards, comprehensive monitoring, and data collection and interpretation;

(3) to encourage and work for international cooperation and coordination between the state of Montana and the Province of British Columbia concerning the undertaking of natural resource monitoring and use of consistent standards for management of resource development activities throughout the North Fork of the Flathead River drainage portion of the Flathead basin;

(4) to encourage economic development and use of the basin's resources to their fullest extent without compromising the present high quality of the Flathead basin's aquatic environment;

(5) to, in the discretion of the commission, undertake investigations of resource utilization and hold public hearings concerning the condition of Flathead Lake and Flathead basin;

(6) to submit a biennial report to the governor and the appropriate committees of the legislature that includes:

(a) a summary of information gathered in fulfillment of its duties under this section;

(b) information on monitoring activities within the Flathead basin concerning the condition of the basin's natural resources, with particular emphasis on Flathead Lake;

(c) the identification of land use and land development trends in the Flathead basin;

(d) any recommendations the commission considers appropriate for fulfillment of its duties and for continued preservation of the Flathead basin in the present high quality of its aquatic resources; and

(e) an accounting of all money received and expended, by source and purpose, for the period since the last report; and

(7) to meet at least semiannually within the Flathead basin, alternating the meeting site between the cities of Kalispell and Polson.

History: En. Sec. 7, Ch. 424, L. 1983.

75-7-305. Commission authority.

(1) The commission may make recommendations to the legislature and the governor and to federal, tribal, provincial, and local agencies for maintenance and enhancement of the quality of natural resources of the Flathead basin.

(2) The commission may receive and expend donations, gifts, grants, and other money necessary to fulfill its duties.

History: En. Sec. 8, Ch. 424, L. 1983: amd. Sec. 1, Ch. 244. L. 1985; amd. Sec. 9, Ch. 628, L. 1989.

75-7-306. Establishment of account. There is established in the state special revenue fund a Flathead Basin Commission account. Money received by the Flathead Basin Commission under 75-7-305 and such other funds as are designated or appropriated for its use must be deposited in the account.

History: En. Sec. 9, Ch. 424, L. 1983, amd Sec. 48, Ch. 281, L. 1983; amd. Sec. 7 Ch 700, L.. 1989.

75-7-307. Special county government authority. The governing body of any county within or bordering upon the Flathead basin may allocate to the Flathead Basin Commission a portion of any money available from coal severance tax allocations or other sources and designated for planning activities.

History: En. Sec. 10, Ch. 424, L. 1983.

75-7-308. Cooperation with other agencies and organizations. To fulfill its duties, the commission shall develop and maintain cooperative programs with federal, state, provincial, tribal, and local agencies or organizations that are responsible for natural resource management and monitoring in the Flathead basin. Participating federal and provincial agencies must be requested to provide adequate funds to participate on the commission and to monitor resources within their areas of responsibility.

History: En. Sec. 11, Ch. 424, L. 1983.

Chapter No. 95

2-15-213. Flathead Basin Commission membership compensation.

(1) There is a Flathead Basin Commission.

(2) The commission consists of 21 members selected as follows:

(a) seven members appointed by the governor from industrial, environmental, and other interests affected by Title 75, chapter 7, part 3, one of whom must be on the governor's staff and who also serves as the executive director;

(b) one member who shall be the commissioner of state lands or his designee;

(c) one member appointed by the Flathead County commissioners;

(d) one member appointed by the Lake County commissioners;

(e) one member appointed by the Confederated Salish and Kootenai Tribes;

(f) one member appointed by the United States department of agriculture, forest service regional forester for the northern region;

(g) one member appointed by the United States department of interior national park service, regional director for the Rocky Mountain region;

(h) one member appointed by the Flathead County conservation district board of supervisors;

(i) one member appointed by the Lake County conservation district board of supervisors;

(j) four ex-officio members appointed respectively by the chief executive of the provincial government of the Province of British Columbia, the regional administrator of the United States environmental protection agency, the regional administrator of the United States department of interior, bureau of reclamation, and the holder of a license issued for the Flathead project under the Federal Power Act;

(k) two ex-officio members who shall be the director of the department of environmental quality and the director of the department of fish, wildlife and parks or their designees.

(3) the commissioners shall serve without pay. Commissioners mentioned in subsection (2) (a) except the commissioner on the governor's staff, are entitled to reimbursement for travel, meals, and lodging while engaged in commission business, as provided in 2-18-501 through 2-18-503.

(4) The commission is attached to the governor's office for administration purposes only.

History: En. Sec. 4, Ch. 424, L. 1983; amd. Sec. 1, Ch. 95, L. 1985; amd. Sec. 1, Ch. 176, L. 1989.

2-15-214. Flathead Basin Commission-term of appointment-quorum-vacancy-chairman-vote. (1) The commission members shall serve staggered 4-year terms.

(2) A majority of the membership, other than ex-officio members, constitutes a quorum of the commission.

(3) A vacancy on the commission must be filled in the same manner as regular appointments, and the member so appointed shall serve for the unexpired term to which he is appointed.

(4) The commission shall select a chairman from among its members. The chairman may make motions and vote.

(5) A favorable vote of at least a majority of all members, except ex-officio members, of the commission is required to adopt any resolution, motion, or other decision of the commission.

History: En. Sec. 5, Ch. 424, L. 1983.

2-15-215. Flathead Basin Commission staff and office location. (1) The executive director of the commission shall be compensated on a pro rata basis from commission funds, calculated upon the time he is required by the governor to serve the commission.

(2) An office for the commission may be established at a community located in the basin, and sufficient and appropriate staff must be assigned to serve the commission.

History: En. Sec. 6, Ch. 424, L. 1983.

Commission Budget

During the past biennium, the Flathead Basin Commission received operational funding from the Resources Indemnity Trust Water Development Fund (RIT). The FBC also seeks financial, in-kind, and volunteer support from other sources. The following information is a summary of sources of funding, contributions received, and financial allocations for the 1997-1998 Biennium. It is intended for general informational purposes only.

Funding	**Sources**
RIT Water Development Fund	$82,899
Funding Allocations	
Staffing	$72,739
Office Operations	
Communications	6,124
Supplies	910
Travel	1,646
Miscellaneous Expenses	1,480
Total Office Operations	$10,160
Total Expenditure	$82,899
Special Projects and Grants	
Monitoring Master Program*	
MDEQ	$70,000
Montana Power Co.	15,000
Flathead National Forest	16,219
Glacier National Park	7,972
Friends of the Wild Swan	2,054
Flathead Lakers, Inc.	2,000
Polson Community Development Corp.	1,000
Lake County Community Development	1,000
Polson Outdoors, Inc.	1,000
Trout Unlimited, Flathead Chapter	1,000
Volunteer Monitor Program	
MDNRC	$6,960
Montana Watercourse	3,580
CSKT/BPS Watershed Coordinator	1,000

*Note: Amounts refer to direct financial contributions in support of the Commission's Monitoring Master Program. Monitoring activities undertaken by larger organizations, particularly the Flathead National Forest, account for a significantly greater contribution to ongoing water quality monitoring efforts in the Flathead Basin.

Additionally, in-kind contributions include technical assistance from The University of Montana Biological Station, Confederated Salish and Kootenai Tribes, MDNRC Forestry Management Bureau, MFWP, MDEQ, Flathead National Forest (USFS), Glacier National Park (NPS), Flathead Conservation District, and Montana Watercourse.

Voluntary Nutrient Reduction Strategy (VNRS) Education Project

MDNRC Grant	$100,000

(Approximately 12 percent of funds have been expended to date. Funds will be used to carry out the VNRS program described on page 7.)

In-Kind and Volunteer Contributions (hours assistance provided*)

Volunteer Monitor Program citizen participants*	1,340
Green Thumb Program (office secretarial assistance)*	2,400
Flathead Basin Commission citizen members*	900
Flathead Valley Community College Service Learning Program*	30
Montana Building (office rent discount)	$1,700

Glossary

Acid precipitation All forms of precipitation that have an acidity lower than normal rainfall (pH 5.6).

Acre-foot The amount of water needed to cover one acre of surface area to the depth of one foot (12 inches).

Aggradation The build-up of sediments at the headwaters of a lake or reservoir or at a point where streamflow slows to the point that it will drop part or all of its sediment load

Algae Simple one-celled or many-celled plants, capable of photosynthesis; usually aquatic.

Algal bloom Rapid growth of algae on the surface of lakes, streams, or ponds; stimulated by nutrient enrichment.

Alluvium Sand, clay, and other earth materials gradually deposited by streams along riverbeds and floodplains.

Analysis of covariance A statistical procedure that examines the relationship between two or more measures simultaneously (i.e., one dependent variable and one or more independent variables).

Anthropogenic Relating to the scientific study of the origin of man; human.

Aquatic Plants or animal life living in, growing in, or adapted to water.

Aquifer Saturated geologic material sufficiently permeable to yield significant quantities of water to wells and springs; described as artesian (confined) or water table (unconfined).

Available nutrient That portion of any element or compound (such as phosphorus and nitrogen) in the soil that can be readily absorbed and assimilated by growing plants.

Bank stabilization	Implementation of measures along a streambank to prevent or reduce bank erosion.
Bank storage	The water which infiltrates the banks of a stream channel during high flows or floods, is stored there, and is released to the stream after the high water recedes.
Basin	A physiographic region bounded by a drainage divide; consists of a drainage system comprised of streams and often natural or man-made lakes. (Also called drainage basin or watershed.)
Best Management Practices (BMPs)	Methods, measures, or practices to prevent or reduce water pollution and to protect other environmental values.
Biochemical Oxygen Demand (B.O.D.)	The quantity of oxygen utilized in the biochemical oxidation of organic matter in a specified time and at a specified temperature. Waste discharges containing high levels of B.O.D. will deplete oxygen supplies in receiving waters..
Biological availability	Refers to the form that a substance or compound can take that can be readily used for plant or animal growth. Depending on their chemical structure, certain compounds are more available for plant growth than others.
Buffer strip	Strips of grass or other erosion-resistant vegetation between a waterway and an area of more intensive land use.
Chlorophyll *a*	The green molecule in plant cells that carries out photosynthesis. It is used as an indicator of plant and algae productivity and acts as an empirical link between nutrient concentrations and other biological phenomena in lakes. Higher values suggest deteriorating water quality.
Cubic feet per second (cfs)	A unit expressing rate of discharge, typically used in measuring streamflow. One cubic foot per second is equal to the discharge in a stream of a cross section one foot wide and one foot deep, flowing with an average velocity of one foot per second; equals 448.8 gallons per minute.
Data base	A collection of information kept in accessible form for purposes of research, comparison and analysis.
Dissolved Oxygen (DO)	The amount of free oxygen dissolved in water and readily available to aquatic organisms.
Easement	A legal instrument enabling the giving, selling, or taking of certain land or water rights without transfer of title, such as for the passage of utility lines.
Effluent	Liquid attributed to human waste, i.e. sewage arising from various uses of water; often refers to waste water from a sewage treatment or industrial plant.
Ephemeral stream	A stream that flows only part time usually during snow melt periods or following rainstorms.
Erosion	The removal or wearing away of soil or rock by water, wind or other forces or processes. Erosion occurs naturally from weathering or runoff, but can be intensified by land clearing practices.

Eutrophication	The addition of nutrients to a body of water. Accelerated by human activities, abundant growth of aquatic plants may consume much of the dissolved oxygen, making the lake uninhabitable for the previous diversity of fish and other aquatic life.
Floodplain	Any normally dry land area that is susceptible to being inundated by water from any natural source. This area is usually lowland adjacent to a stream or lake.
Fluvial deposits	Sediments deposited by river action.
Fresh water	Water without salinity.
Groundwater	The supply of fresh water that forms a natural reservoir under the earth's surface in soil and bedrock.
Groundwater recharge	The natural renewal of ground water supplies by infiltration of rain or recharge other precipitation through the soil.
Hydrograph	A graph showing the changes in discharge of a stream or river, or the changes in water levels of a well with the passage of time.
Hydrology	The area of science dealing with the study of the waters of the earth and its atmosphere.
Hypolimnion	The lowermost, non-circulating layer of cold water in a thermally stratified lake; usually deficient of oxygen.
Instream flows	The water left in a stream to maintain the existing aquatic resources and associated wildlife and riparian habitat.
Labile	Constantly undergoing or likely to undergo chemical change; unstable.
Leaching	The removal of nutrients, chemicals or contaminants from the soil by water movement through the soil.
Limnology	The area of science dealing with the study of freshwater aquatic ecology.
Mass flux	The input or gain and output or loss of materials (such as nutrients) to an area such as a body of water.
Mass wasting	A general term for a variety of processes by which large masses of earth material are moved by gravity either slowly or quickly from one place to another.
Mesotrophic	Descriptive of lakes in transition from oligotrophic status toward eutrophic. They are still generally pristine, but fish species are mixed, nutrient levels are higher and water is not quite as crystal clear.
Mitigation	An action designed to lessen or reduce adverse impacts; frequently used in the context of environmental assessment.
Nitrogen	A primary chemical element which is a part of all plant and animal tissues. It can promote algal blooms that cause eutrophication if it runs off or leaches out of the surface soil.
Nonpoint source	A diffuse source of water pollution that does not discharge through a pipe.

Nutrients	Elements or compounds essential to life, including carbon, oxygen, nitrogen, phosphorus, and many others.
Nutrient budget	The quantity of a given element or compound available for plant productivity over time. Changes in plant productivity are directly related to changes in the nutrient budget.
Nutrient loading	Increases in the nutrient budget attributed to either increases from human-related or natural events.
Oligotrophic	Descriptive of crystal-clear lakes characterized by cold water fish species, low nutrient content and generally pristine features.
Ortho phosphorus	The form of phosphorus most available to algae for growth.
Particulate organic carbon	Carbon content of particles in the water derived from living organisms (includes algae, waste products, dead or decayed organisms)
Permeability	The capacity of porous rock, sediment, or soil to transmit water.
pH	A measure that indicates the relative acidity or alkalinity of a substance. The pH scale ranges from 0 (most acid) to 14 (most basic), with a pH of 7 being neutral.
Phaeophytin	Formed when Chlorophyll *a* degrades. Data are used to correct for degradation of Chlorophyll *a* that might occur between sample collection and analysis.
Phosphorus	One of the primary nutrients required for the growth of aquatic plants and algae. Phosphorus is often the limiting nutrient for the growth of these plants. (See nitrogen.)
Point source	Discrete sources of pollution, such as pipes, ditches, channels, wells, containers, or other vessels.
Pollution	Any contaminant or impurity.
Primary productivity	The ability of a body of water to grow algae, measured as grams of carbon per square meter.
Recharge	The processes involved in the addition of water to the zone of saturation; also the amount of water added.
Revegitation	The planting of ground cover on highly erodible and marginal lands as a means of preventing further erosion.
Riparian	Located or living along or near a stream, river or body of water.
River hydrograph	The pattern of a river or lake expressed as in-flow and out-flow ratios (such as cubic feet per second) and containing temperature, chemical and other expected characteristics.
Runoff	Water from rain, snow melt, or irrigation that flows over the ground surface and returns to streams. It can collect pollutants from air or land and carry them to the receiving waters.
Secchi Disk	A 20cm reflective disk used by volunteers and professional researchers to determine water clarity and derive a value used in computing a lake's trophic status.

Sediment	Solid material (silt, sand, or organic matter) that has been moved from its site of origin and has settled to the bottom of a watercourse or water body. Excessive amounts can clog a watercourse. If disturbed, it can contribute to turbidity.
Sedimentation	The deposition of sediment from a state of suspension in water or air.
Solubility	The capacity to be dissolved or liquefied.
Suspended solids	Solids floating in the water column that generally impart a cloudy appearance to water, sewage, or other liquids.
Terrestrial	Living or growing on land rather than in water or air.
Tertiary waste	Selected biological, physical, and chemical separation processes to remove organic and treatment inorganic substances that resist conventional secondary treatment practices.
Total Maximum Daily Load (TMDL)	A U.S. Environmental Protection Agency determined level of pollution that can be permitted to enter a body of water if water quality is to be maintained.
Total suspended solids (TSS)	Solids, found in waste water or in a stream, which can be removed by filtration. The origin of suspended matter may be man-made wastes or natural sources such as silt.
Tributary	A steam that contributes its water to another stream or body of water.
Trophic status	The descriptive phase of a lake: oligotrophic, mesotrophic, eutrophic or somewhere in between. (Flathead Lake currently is described as oligomesotrophic).
Turbidity	Haziness or cloudiness in water because of suspended silt or organic matter.
Voluntary Nutrient Reduction Strategy (VNRS)	The voluntary strategy through which the Flathead Basin Commission will work with local groups and individuals to identify and implement the non-regulatory means to achieve the Total Maximum Daily Load (TMDL) for Flathead Lake.
Water column	A cross section of a body of water from a point on the surface, straight down to the bottom.
Water cycle	The continuous circulation of water in systems throughout the planet, involving condensation, precipitation, runoff, evaporation and transpiration.
Water pollution	The presence of harmful material in water in sufficient quantities to result in a measurable degradation of the water quality.
Water quality	A term used to describe the chemical, physical, and biological characteristics of water with respect to its suitability for a particular use.
Watershed	The area of land that drains into a particular watercourse or water body.
Wetlands	Any land area that tends to be regularly wet or flooded.
Zooplankton	Plankton that is composed of tiny animals and animal matter.

Website Directory

Flathead Basin Commission
www.montanaweb.com/FBC/
Information on activities of the Commission, plus access to water quality data.

Montana Volunteer Water Monitoring Project
http://nris.mt.gov/wis/volwatmon.htm
Updates on volunteer water quality monitoring projects throughout the state.

Project FREEFLOW
www.cyberport.net/users/dons
A source for water quality information produced by Flathead area students.

Montana Natural Resource Information System (NRIS)
http://nris.mt.gov/
Varied information on Montana's natural resources, including water quality.

Montana Water Center
http://water.montana.edu
Provides updates on this MSU-based project and The Montana Watercourse.

Flathead Lake Biological Station (UM)
www.umt.edu/biology/flbs
Information on this world class research center on Flathead Lake.

Montana Department of Environmental Quality
www.deq.state.mt.us
Contains information relating to TMDL and other environmental issues.

Montana Watershed Coordination Council
http://water.montana.edu/docs/watersheds/MWCChome.htm
Coordinates information from citizen groups and agencies involved in watershed projects.

Montana Department of Natural Resources and Conservation
www.dnrc.state.mt.us
Information about water resources in Montana and this agency's activities.

Montana Fish, Wildlife and Parks
http://fwp.mt.gov/
Contains hunting, fishing and parks information, plus means of reporting violations.

North American Lake Management Society
www.nalms.org/
Information about lake management issues, forming lake associations.

U.S. Environmental Protection Agency
www.epa.gov/surf2/
This site allows the user to search for maps of local watersheds.

The Great American Secchi Dip-In
http://humboldt.kent.edu/~dipin
Summarized volunteer data gathered from programs around the U.S. and Canada.

U.S. Geological Survey National Water Quality Assessment Program
wwwrvares.er.usgs.gov/nawqa/nawqa_home.html
Provides information being developed on surface and ground water quality.

Natural Resources Conservation Service (NRCS)
www.ncg.nrcs.usda.gov
Features general natural resource information and agency data.

Notes

Notes

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